PB91-145664

Annual Hazardous Waste Research Symposium (16th) Remedial Action, Treatment and Disposal of Hazardous Waste Held in Cincinnati, Ohio on April 3-5, 1990

(U.S.) Environmental Protection Agency, Cincinnati, OH

Apr 90

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Abstract: The report includes different processes for treatment of waste. Some of these papers include: Thermal degradation, waste minimization; Biological and chemcial treatment, ozone/ultraviolet light, steam stripping, and solvent washing of contaminated soil.

PB91-145664

United States
Environmental Protection
Agency

Risk Reduction Engineering Laboratory
Cincinnati, Ohio 45268
Edison, New Jersey 08837

Research and Development

CERI-90-04

EPA

Sixteenth Annual Hazardous Waste Research Symposium

Remedial Action, Treatment and Disposal of Hazardous Waste

The Westin Hotel
Cincinnati, Ohio
April 3 through 5, 1990

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U.S. DEPARTMENT OF COMMERCE
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SPRINGFIELD, VA 22161

Hotel Map 2
Program 3
Session A Abstracts 13
Session B Abstracts 31
Session C Abstracts 51

All meeting rooms
have been designated
No Smoking areas.

CERI-90-04
April 1990

Sixteenth Annual Hazardous Waste Research Symposium

Remedial Action, Treatment and Disposal of Hazardous Waste

Sponsored by:
Risk Reduction Engineering Laboratory
Cincinnati, OH 45268
Edison, NJ 08837

E. Timothy Oppelt, Director

Marta K. Richards, Project Officer
Eugene F. Harris, Project Officer
Teri Shearer, Project Officer
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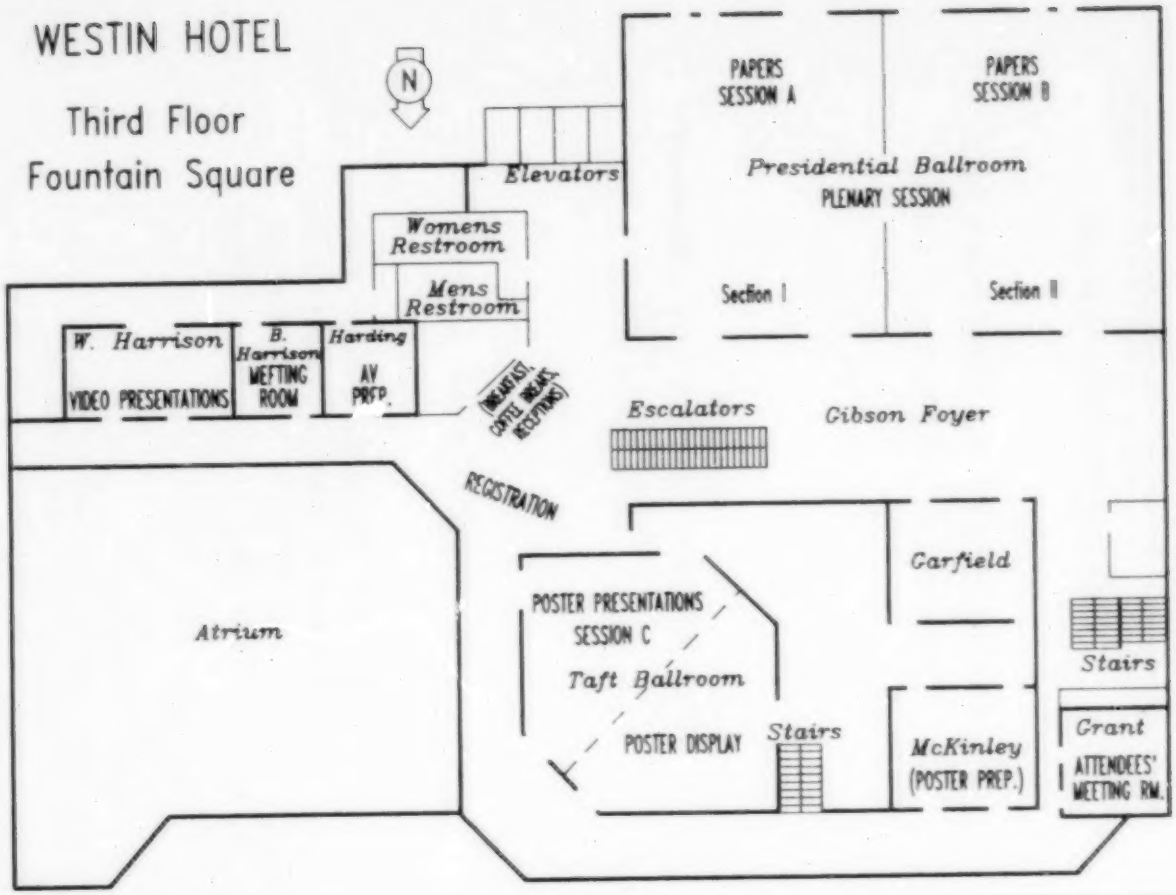
WESTIN HOTEL
Third Floor
Fountain Square
N
PAPERS SESSION A
PAPERS SESSION B
Elevators
Presidential Ballroom
PLENARY SESSION
Womens Restroom
Mens Restroom
Section I
Section II
W. Harrison
VIDEO PRESENTATIONS
B. Harrison
MEETING ROOM
Harding
AV PREP.
(REGISTRATION CONFERENCE MANAGEMENT RECEPTIONIST)
Escalators
Gibson Foyer
REGISTRATION
Atrium
Carfield
POSTER PRESENTATIONS
SESSION C
Taft Ballroom
POSTER DISPLAY
Stairs
McKinley
(POSTER PREP.)
Stairs
Grant
ATTENDEES' MEETING RM.

MONDAY, APRIL 2

Meet the RREL Professional Staff -- Cocktail Reception (Cash Bar)
6:00 - 9:00 pm, Taft Ballroom

REGISTRATION
6:00 - 8:30 pm, Gibson Foyer

TUESDAY, APRIL 3

REGISTRATION
Starting at 7:00 am, Gibson Foyer

Cash Continental Breakfast
7:30 - 9:00 am

PLENARY SESSION

9:00 am	**WELCOME REMARKS** **E. Timothy Oppelt, Director** Risk Reduction Engineering Laboratory U.S. Environmental Protection Agency, Cincinnati, OH
9:15 am	**SUPERFUND ACTIVITIES** **Henry L. Longest, II, Director** Office of Emergency and Remedial Response U.S. Environmental Protection Agency, Washington, DC
9:45 am	**BREAK**
10:15 am	**RCRA ACTIVITIES** **Jeffery D. Denit, Deputy Director** Office of Solid Waste U.S. Environmental Protection Agency, Washington, DC
10:45 am	**A STATE PERSPECTIVE** **Richard L. Shank, Director** Ohio EPA, Columbus, OH
11:15 am	**Question and Answer Period**
12:00 noon	**LUNCH (Delmonico's Restaurant -- Ticket Holders Only)** **Poster Displays Open, Taft Ballroom**

TUESDAY, APRIL 3 (Continued)

	A - PAPERS (Presidential I)	B - PAPERS (Presidential II)	C - POSTERS (Taft Ballroom)
Session	**1-A Thermal Destruction I**	**1-B Biotechnology I**	**1-C Posters**
Moderators:	George L. Huffman U.S. EPA, RREL	Henry H. Tabak U.S. EPA, RREL	
1:30 pm	**PIC Minimization and Control Strategies for Full-Scale Thermal Disposal Systems** • Barry Dellinger University of Dayton Research Institute Dayton, OH	**Evaluating the Ability of Recombinant Bacteria to Degrade PCBs on Soil** • Frank J. Mondello General Electric Company Schenectady, NY	**Guide for Conducting Treatability Studies Under CERCLA** • Jonathan G. Herrmann U.S. EPA, RREL Cincinnati, OH
2:00 pm	**Parametric Evaluation of Metal Partitioning at the U.S. EPA Incineration Research Facility** • Gregory J. Carroll U.S. EPA, RREL Cincinnati, OH	**Degradation of Chlorinated Biphenyls by Escherichia coli Containing Cloned Genes of the Pseudomonas putida F1 Toluene Catabolic Pathway** • Sadhana Chauhan University of Iowa Iowa City, IA	**Implementing a Waste Minimization Program at the A. W. Breidenbach Environmental Research Center** • Brian Westfall U.S. EPA, RREL Cincinnati, OH
2:30 pm	**Sorption and Desorption of POHCs and PICs in a Full-Scale Boiler Under Sooting Conditions** • Robert E. Sommerlad Midwest Research Institute Falls Church, VA	**Use of DNA Hybridization Probes in the Monitoring of Biotreatment Systems** • Richard A. Haugland University of Cincinnati Cincinnati, OH	**Biological and Physico-Chemical Remediation of a Mercury-Contaminated Hazardous Waste** • C.L. Hansen Utah State University Logan, UT
3:00 pm		**BREAK**	

Session	2-A Thermal Destruction II	2-B Biotechnology II	2-C Posters
Moderators:	Robert C. Thurnau U.S. EPA, RREL	Albert D. Venosa U.S. EPA, RREL	
3:30 pm	**State-of-the-Art Assessment of Medical Waste Thermal Treatment** • R.G. Barton Energy and Environmental Research Corp. Irvine, CA	**Biodegradability Studies of the Alaskan Weathered Crude Oil Constituents with the Use of Electrolytic Respirometry and Shaker Flask Systems** • Henry H. Tabak U.S. EPA, RREL Cincinnati, OH	**Steam Stripping and Batch Distillation for Removal and/or Recovery of Volatile Organic Compounds** • Sardar Q. Hassan University of Cincinnati Cincinnati, OH
4:00 pm	**The Incineration of Arsenic-Contaminated Soils Related to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)** • Howard O. Wall U.S. EPA, RREL Cincinnati, OH	**Biological Treatment of Wastewater Containing Hazardous Organic Compounds: 2-Ethoxyethanol** • Margaret J. Kupferle University of Cincinnati Cincinnati, OH	**Ozone/Ultraviolet Light Treatment of Ferri-Cyanide Complexes** • Mark J. Briggs PEI Associates Cincinnati, OH
4:30 pm	**Fundamental Studies on Particulate Emissions from Hazardous Waste Incinerators** • Pratim Biswas University of Cincinnati Cincinnati, OH	**Bench-Scale Biodegradation Studies with Organic Pollutants Using White Rot Fungus** • Susan Strohofer University of Cincinnati Cincinnati, OH	**Solvent Washing of Contaminated Soil** • William C. Webster Harmon Environmental Services Auburn, AL

RECEPTION 5:00 pm, Gibson Foyer (Cash Bar)

DINNER Montgomery Inn, 7:00 pm (ticket-holders only)

WEDNESDAY, APRIL 4

Cash Continental Breakfast 7:00 am - 8:30 am, Gibson Foyer

	A - PAPERS (Presidential I)	B - PAPERS (Presidential II)	C - POSTERS (Taft Ballroom)
Session	**3-A Air Emission/Oxidation**	**3-B Protective Clothing/Soil Washing**	**3-C Posters**
Moderators:	H. Paul Warner U.S. EPA, RREL	Michael Gruenfeld U.S. EPA, RREL	
8:30 am	**Fate of Volatiles in Wastewater Treatment** • Richard A. Dobbs U.S. EPA, RREL Cincinnati, OH	**Experimental Methods/Results of Assessing Soil Washing Technology** • Mary E. Tabak Camp Dresser & McKee, Inc. Boston, MA	**The U.S. EPA WRITE Program** • Paul M. Randall U.S. EPA, RREL Cincinnati, OH
9:00 am	**Field Assessment of Air Emissions from Hazardous Waste Dewatering Operations** • Thomas C. Ponder, Jr. PEI Associates, Inc. Arlington, TX	**Vacuum-Assisted Steam Stripping to Remove Pollutants from Contaminated Soil --A Laboratory Study** • Arthur E. Lord, Jr. Drexel University Philadelphia, PA	**American Institute for Pollution Prevention** • Thomas R. Hauser University of Cincinnati Cincinnati, OH
9:15 am	**Bus Departs Hotel for First Tour of EPA's Center Hill Facility**		
9:30 am	**Bench-Scale Wet-Air Oxidation of Complexed Metal Cyanide Sludges** • Ronald J. Turner U.S. EPA, RREL Cincinnati, OH	**Limited-Use Chemical Protective Clothing for EPA Superfund Activities** • Jack C. Sawicki Arthur D. Little, Inc. Cambridge, MA	**EPA's Pollution Prevention Information Clearinghouse** • Myles Morse U.S. EPA, OEETD Washington, DC
10:00 am	**BREAK**		

Session	4-A Innovative Techniques	4-B Landfill	4-C Posters
Moderators:	Norma M. Lewis U.S. EPA, RREL	David A. Carson U.S. EPA, RREL	
10:30 am	**Passive Treatment of Metals Mine Drainage Through Use of a Constructed Wetland: Evaluation of Operation** • Thomas R. Wildeman Colorado School of Mines Golden, CO	**Stress Cracking of Polyethylene FMLs** • Robert M. Koerner Drexel University Philadelphia, PA	**IRF Update 1990** • Robert C. Thurnau U.S. EPA, RREL Cincinnati, OH
11:00 am	**Soil Vapor Extraction Research Efforts** • Thomas A. Pedersen Camp Dresser & McKee, Inc. Boston, MA	**Landfill Test Cells** • N.C. Vasuki Delaware Solid Waste Authority Dover, DE	**Development and Demonstration of a Pilot-Scale Debris Washing System** • Michael L. Taylor PEI Associates, Inc. Cincinnati, OH
11:30 am	**AlgaSORB®: A New Technology for Removal and Recovery of Metal Ions from Groundwaters** • Dennis W. Darnall Bio-Recovery Systems, Inc. Las Cruces, NM	**Revision of the HELP Model** • Paul R. Schroeder U.S. Army Corps of Engineers Vicksburg, MS	**Engineering Handbook for Hazardous Waste Incineration** • Leo Weitzman LVW Associates Inc. Durham, NC
12:00 noon	**LUNCH (Delmonico's Restaurant - Ticket holders only)**		
1:15 pm	**Bus Departs Hotel for First Tour of EPA's T & E Facility**		

WEDNESDAY, APRIL 4 (Continued)

	A – PAPERS (Presidential I)	B – PAPERS (Presidential II)	C – POSTERS (Taft Ballroom)
Session	**5-A SITE**	**5-B Waste Minimization I**	**5-C Posters**
Moderators:	John F. Martin U.S. EPA, RREL	Paul Randall U.S. EPA, RREL	
1:30 pm	**A SITE Demonstration of Ultrox UV/Oxidation Technology** • Norma M. Lewis U.S. EPA, RREL Cincinnati, OH	**Waste Minimization Assessments at Selected DOD Facilities** • James S. Bridges U.S. EPA, RREL Cincinnati, OH	**Assessment of the Current SOTA for Bio/Photodegradable Plastics** • Roxanne B. Sukol PEI Associates, Inc. Cincinnati, OH
2:00 pm	**SITE Demonstration of a Biological Treatment of Groundwater by BioTrol, Inc. at a Wood Preserving Site in New Brighton, MN** • William H. Hahn SAIC Paramus, NJ	**Chemical Substitution of Trichloroethylene and Methanol in Manufacturing Operations** • Lisa Brown U.S. EPA, RREL Cincinnati, OH	**Field Tests of Hydraulic Fracturing to Increase Fluid Flow in Soils** • Larry C. Murdoch University of Cincinnati Cincinnati, OH
2:30 pm	**SITE Demonstration of a Soil Washing System by BioTrol, Inc. at a Wood Preserving Site in New Brighton, MN** • William D. Ellis SAIC McLean, VA	**Waste Minimization Assessment Centers** • F. William Kirsch University City Science Center Philadelphia, PA	**Barrier Equivalency of Liner and Cap Materials** • David E. Daniel University of Texas–Austin Austin, TX
3:00 pm	**BREAK**		

Session	6-A Underground Storage Tanks	6-B Waste Minimization II	6-C Posters
Moderators:	Anthony N. Tafuri U.S. EPA, RREL	Teresa M. Harten U.S. EPA, RREL	
3:30 pm	**Characterization of Internal Inspection Procedures and Equipment for Underground Storage Tanks** • Susan E. Rohland PEI Associates, Inc. Edison, NJ	**Veterans Administration Hospital Waste Minimization Case Study--Cincinnati, Ohio** • Kenneth R. Stone U.S. EPA, RREL Cincinnati, OH	**SITE Demonstration of the AWD's AquaDetox/VES System** • Gordon M. Evans U.S. EPA, RREL Cincinnati, OH
4:00 pm	**Evaluation of Internal Leak Detection Technology for Large USTs** • Joseph W. Maresca, Jr. Vista Research, Inc. Mountain View, CA	**A Ten-Year Review of Plastics Recycling in the U.S. and Europe** • S. Garry Howell U.S. EPA, RREL Cincinnati, OH	**Guidance on Metals and PICs Control from Hazardous Waste Incineration** • Shiva Garg U.S. EPA, OSW Washington, DC
4:30 pm	**Sources of Contamination Associated with Closure of Underground Storage Tanks** • Warren J. Lyman Camp Dresser & McKee, Inc. Boston, MA	**Evaluation of EPA Waste Minimization Assessment** • Mary Ann Curran U.S. EPA, RREL Cincinnati, OH	**Reduction of Transient Puffs from a Rotary Kiln Incinerator: The Role of the Secondary Combustion Chamber** • Paul M. Lemieux U.S. EPA, AEERL Research Triangle Park, NC

RECEPTION, 5:00 pm, Gibson Foyer (Cash Bar)

THURSDAY, APRIL 5

	Cash Continental Breakfast 7:00 am - 8:30 am, Gibson Foyer		
	A - PAPERS (Presidential I)	B - PAPERS (Presidential II)	C - POSTERS (Taft Ballroom)
Session Moderators:	**7-A Thermal Destruction III** Franklin Alvarez U.S. EPA, RREL	**7-B Biotechnology III** Naomi P. Barkley U.S. EPA, RREL	**7-C Posters**
8:30 am	**Removal of Soluble Toxic Metals from Water** • Leo P. Buckley Atomic Energy of Canada, Ltd. Chalk River, Ontario, Canada	**Slurry-Based Biotreatment of Still Bottoms Sorbed onto Soil Fines** • Robert C. Ahlert Rutgers University Piscataway, NJ	**The Use of Electrokinetics for Hazardous Waste Site Remediation** • Joseph T. Swartzbaugh PEER Consultants, P.C. Dayton, OH
8:45 am	**Bus Departs Hotel for Second Tour of EPA's Center Hill Facility**		
9:00 am	**Laboratory Studies of the Thermal Destruction of Toxic Organics in Sewage Sludge** • Barry Dellinger University of Dayton Research Institute Dayton, OH	**Anaerobic Treatment of Leachate** • Sanjoy K. Bhattacharya University of Cincinnati Cincinnati, OH	**Ground Penetrating Radar-Equipped Field Robotic Vehicle for Surveying CERCLA Sites** • James F. Osborn Carnegie Mellon University Pittsburgh, PA
9:30 am	**Predicted and Observed Organic Emissions from Sewage Sludge Incineration** • D.A. Tirey University of Dayton Research Institute Dayton, OH	**The Effects of Temperature, Concentration of Substrate and Microbial Inoculum, and the Source of Sludge Biomass on the Kinetics of Biodegradation** • Henry H. Tabak U.S. EPA, RREL Cincinnati, OH	**Detoxification of Released Vapors/Particulates by Entrapment in Chemically Active Foams** • Patricia M. Brown F.W. Enviresponse, Inc. Edison, NJ
9:45 am	**Bus Departs Hotel for Second Tour of EPA's T & E Facility**		
10:00 am	**BREAK**		

Session	8-A Ash/Permeability	8-B Treatment/Geotextiles	8-C Posters
Moderators:	Charles I. Mashni U.S. EPA, RREL	Ronald J. Turner U.S. EPA, RREL	
10:30 am	**Characterization of Two MWC Ashes and Leachates -- A Field Study** • Haria Roffman NUS Corp. Pittsburgh, PA	**Chemical Compatibility of Geotextiles, Geonets, and Pipes Used in Hazardous Waste Containment** • Patrick E. Cassidy Southwest Texas State University San Marcos, TX	**Assessment of Material Handling Technologies** • Majid A. Dosani PEI Associates, Inc. Cincinnati, OH
11:00 am	**Mobility of Dioxins and Furans Associated With Stabilized Incineration Residues in the Marine Environment** • Frank Roethel Waste Management Institute Stony Brook, NY	**Stabilization/Solidification for Treatment of Superfund Soils** • Franklin R. Alvarez U.S. EPA, RREL Cincinnati, OH	**Excalibur Ozone/Ultraviolet/ Ultra Sonics** • Lucas Boeze Excalibur Enterprises, Inc. Key Biscayne, FL
11:30 am	**Water Movement Through an Experimental Soil Liner** • Ivan G. Krapac Illinois State Geological Survey Champaign, IL	**Treatability of Tributyltin in POTWs** • Richard A. Dobbs U.S. EPA, RREL Cincinnati, OH	**Metal Treatment by Adsorptive Filtration** • Mark M. Benjamin University of Washington Seattle, WA

SESSION A
ABSTRACTS

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PIC MINIMIZATION AND CONTROL STRATEGIES FOR FULL-SCALE THERMAL DISPOSAL SYSTEMS

Philip H. Taylor, Barry Dellinger, Debra A. Tirey, and Richard C. Striebich
University of Dayton Research Institute
Dayton, OH

C.C. Lee
U.S. EPA, RREL
Cincinnati, OH

Control of emissions of toxic organic and organometallic compounds from thermal disposal systems burning hazardous materials is one of the major technical and sociological issues surrounding the further implementation of thermal destruction as a waste disposal alternative. This manuscript proposes several minimization and control options for organic products of incomplete combustion (PICs) as determined by relating the following two factors: 1) rank-order statistical analyses of full-scale and pilot-scale organic emissions versus operating parameters, and 2) chemical kinetic analyses of the laboratory-scale PIC data base. Proposed PIC minimization and control strategies include: 1) positive temperature gradient in combustion zones, 2) plug flow design for combustion zones, 3) low precursor concentrations, 4) low Cl:H molar ratio, 5) homogeneous feed, and 6) slow quenching rate. Although the data base is limited, present results suggest that radical-molecule and radical recombination reactions are the dominant emissions source mechanisms in full-scale systems. The relative importance of the proposed PIC minimization and control options in relation to the dominant PIC formation mechanisms will be discussed.

PARAMETRIC EVALUATION OF METAL PARTITIONING AT THE U.S. EPA INCINERATION RESEARCH FACILITY

Gregory J. Carroll
U.S. EPA, RREL
Cincinnati, OH

Larry R. Waterland and Donald J. Fournier, Jr.
Acurex Corporation
Mountain View, CA

Two series of tests were performed at EPA's Incineration Research Facility (IRF) to evaluate the fate of trace metals fed to a pilot-scale rotary kiln incinerator. Objectives of the tests included identification of: 1) the distribution of metal emissions among ash, scrubber water, and flue gas; 2) the sensitivity of metal fate to operating conditions (kiln and afterburner temperatures) and waste feed characteristics (chlorine content); 3) the collection efficiency of the air pollution control device (APCD); and 4) the predictive capabilities of a numerical partitioning model.

The two test series were similar in all respects with the exception of the device used for particulate and acid gas control. In the first series, the

primary APCD consisted of a venturi scrubber followed by a packed column scrubber. In the second series, an ionizing wet scrubber was evaluated as the primary APCD.

Synthetic waste formulations contained five hazardous trace metals (arsenic, barium, cadmium, chromium, and lead) and four non-hazardous trace metals (bismuth, copper, magnesium, and strontium) spiked onto a clay absorbent material. Test variable ranges were as follows: waste feed chlorine content (0 to 8%), kiln temperature (816° to 927°C), and afterburner temperature (982° to 1,204°C).

This paper discusses the results and conclusions of the research project.

SORPTION AND DESORPTION OF POHCs AND PICs IN A FULL-SCALE BOILER UNDER SOOTING CONDITIONS

Robert E. Sommerlad
Midwest Research Institute
Falls Church, VA

Gary D. Hinshaw
Midwest Research Institute
Kansas City, MO

Industrial boilers are capable of achieving a destruction and removal efficiency (DRE) of 99.99 percent for RCRA-listed toxic organics. Results from recent test programs, however, have shown that unburned principal organic hazardous constituents (POHCs) and products of incomplete combustion (PICs) can continue to be released after waste cofiring ceases. Based upon previous experiments in a pilot-scale boiler it appears that some of the POHC s and PICs can be adsorbed on soot deposited on boiler surfaces during cofiring and then desorbed back into the stack gases after waste cofiring ceases, an effect referred to as hysteresis. Tests were conducted on a full-scale boiler to determine the magnitude of this hysteresis effect. The objective was to quantify the adsorption of organic compounds on combustion-generated soot during the cofiring of POHCs with fuel oil. The test was designed as a "range-finding" study under non-optimum operating conditions involving soot generation to determine if soot sorption may be a major factor in organic emissions relative to trial burns. The test involved cofiring trichloroethylene and monochlorobenzene with No. 6 fuel oil under both non-sooting and sooting conditions to evaluate desorption of organics. Sampling involved collection of soot on boiler surfaces and in the flue gas for organic analysis as well as stack testing using a volatile organic sampling train (VOST) for POHCs and volatile PICs; Modified Method 5 (MM5) for semivolatile PICs; continuous emission monitors (CEMs) for oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), and total hydrocarbons (THC); and a field gas chromatograph (GC) involving semicontinuous measurements of POHCs via a cryogenic sample concentrator. This paper summarizes the results of the study.

STATE-OF-THE-ART ASSESSMENT OF MEDICAL WASTE THERMAL TREATMENT

R.G. Barton, W.S. Lanier, and W.R. Seeker
Energy and Environmental Research Corporation
Irvine, CA

C.C. Lee
U.S. EPA, RREL
Cincinnati, OH

Medical waste treatment and disposal is an increasingly imposing public health crisis. Incineration has proven to be an effective means of reducing the volume and hazard of medical waste. However, recent studies indicate that medical waste incinerators may emit high concentrations of some toxic compounds, including chlorinated dioxins, toxic metals, and acid gases.

This study assessed the state of the art of medical waste thermal treatment. The program involved a survey of existing information on medical waste treatment. This information was combined with data from municipal and hazardous waste combustion to identify potential mechanisms responsible for toxic emissions. Manufacturers of combustion and flue gas cleaning equipment were contacted. Information on current design practice was obtained.

It was determined that many of the same mechanisms responsible for toxic emissions from municipal waste incineration systems are also responsible for emissions from medical waste incinerators. However, medical waste incinerators present unique challenges due to their size and the heterogeneity of the waste.

THE INCINERATION OF ARSENIC-CONTAMINATED SOILS RELATED TO THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

Howard O. Wall and Marta K. Richards
U.S. EPA, RREL
Cincinnati, OH

The fate of arsenic in CERCLA soils and synthetic soils has been evaluated at the U.S. EPA Incineration Research Facility (IRF) at Jefferson, Arkansas. Studies were performed in the IRF's pilot-scale batch-feed rotary kiln incinerator. The results indicate that, although arsenic is a highly volatile metal, about 90 percent of the measured arsenic fed to the kiln is contained in the kiln ash; about 5 percent is removed by the air pollution abatement system; and the other 5 percent is in the particulate emissions. Muffle furnace tests indicate that both the volatility and leachability of arsenic are reduced when lime is added to the arsenic-containing soil before incineration.

FUNDAMENTAL STUDIES ON PARTICULATE EMISSIONS FROM HAZARDOUS WASTE INCINERATORS

V. Sethi and P. Biswas
Department of Civil and Environmental Engineering
University of Cincinnati
Cincinnati, OH

A fundamental study has been made to understand the formation and growth of metallic particulate emissions in hazardous waste incinerators. A bench-scale flame incinerator was used to perform controlled experiments with silicon and lead compounds. A dilution probe and real time aerosol instruments were used to measure the particle size distributions at different locations in the flame region. A lognormal aerosol model has been developed to predict the evolution of the particle size distributions. The model accounts for particle formation by nucleation and chemical reaction and growth by condensation and coagulation. The effect of presence of seed, its size, and concentration on submicron emissions has been studied. The experimental results and model predictions are compared.

FATE OF VOLATILES IN WASTEWATER TREATMENT

Richard A. Dobbs
U.S. EPA, RREL
Cincinnati, OH

Sanjoy H. Bhattacharya*
Department of Civil and Environmental Engineering
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Cincinnati, OH

The fate of organics in conventional primary/activated sludge treatment is controlled by several integrated removal mechanisms which operate simultaneously. The major mechanisms include: 1) sorption on solids and biomass, 2) volatilization to the atmosphere through surface desorption and air stripping, and 3) biodegradation or transformation by aerobic and/or anaerobic processes. An overview of the role of these mechanisms and other factors which control the fate and removal of volatile organic compounds in wastewater treatment plants will be discussed. Treatability data for selected volatile compounds from the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lists of compounds have been obtained in a large-scale pilot plant study.

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*Now affiliated with Tulane University, New Orleans, LA

FIELD ASSESSMENT OF AIR EMISSIONS FROM WASTE DEWATERING OPERATIONS

Thomas C. Ponder, Jr. and Cynthia J. Bishop
PEI Associates, Inc.
Arlington, TX

Petroleum companies generate millions of tons of sludge every year from American Petroleum Institute separators, Dissolved Air Floats, and biological waste. This sludge is often dewatered with belt filter presses, rotary vacuum drums, centrifuges, and plate and frame presses to reduce the volume of solid waste that will be disposed. Since the sludge is derived from petroleum products, a variety of volatile and semi-volatile organics can be found in the sludge mixture. Since sludges are often heated and dewatering equipment is open to the atmosphere, the sludge dewatering process has a potential to release these organics to the air. Organic concentrations as high as 5,000 ppm have been found at the vents from a dewatering building. This paper presents the results of a comprehensive study that was performed for the EPA to quantify the release of volatile and semi-volatile organics from sludge dewatering operations. The study included field tests of three dewatering operations in which material balances were calculated around the dewatering processes.

BENCH-SCALE WET-AIR OXIDATION OF COMPLEXED METAL CYANIDE SLUDGES

Ronald J. Turner
U.S. EPA, RREL
Cincinnati, OH

Certain aqueous and solid hazardous wastes from metal finishing and electroplating operations contain metal-cyanide complexes which must receive treatment to significantly reduce the cyanide concentrations prior to disposal. The applicable processes for treating these wastes include alkaline chlorination, electrolytic oxidation, ultraviolet light/ozone, hydrolysis, and wet-air oxidation (WAO). Resource Conservation Recovery Act (RCRA) wastes F006, F007, and F019 were treated by liquid-phase oxidation to determine the effectiveness of cyanide destruction by WAO as measured by the total and amenable cyanide concentrations in the oxidized effluent and filtered solids.

PASSIVE TREATMENT OF METALS MINE DRAINAGE THROUGH USE OF A CONSTRUCTED WETLAND: EVALUATION OF OPERATION

S.D. Machemer, P.R. Lemke, T.R. Wildeman, R.R. Cohen, and R.W. Klusman
Colorado School of Mines
Golden, CO

Edward R. Bates
U.S. EPA, RREL
Cincinnati, OH

A research site for passive mine drainage treatment was designed and constructed at the Big Five Tunnel, one of several CERCLA sites within the Idaho Springs–Central City mining district in Colorado. After two years of operation, the objective of removal of heavy metals has been met in the pilot–scale system. On the average, Cu has been reduced from 0.9 mg/L to less than 0.05 mg/L, and Zn has been reduced from 9.0 to less than 0.05 mg/L. These metals are removed by precipitation of sulfides produced by the reduction of sulfate by anaerobic bacteria. Iron is also reduced in the anaerobic system from 40 mg/L to 15 mg/L, and pH is increased from below 3 to above 6. These results have been achieved after two major redesigns from the initial construction of the wetland. Mn is not removed from the mine drainage. Since its removal is best achieved at higher pHs, a second stage of wetland after the anaerobic stage would best achieve this.

SOIL VAPOR EXTRACTION RESEARCH EFFORTS

Tom A. Pedersen
Camp Dresser & McKee, Inc.
Boston, MA

Chi–Yuan Fan
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Soil vapor extraction (SVE) systems are being utilized at an increasing frequency for remediation of releases from underground storage tank sites. The swelling interest in these technologies is due in part to their demonstrated effectiveness for volatile removal and the apparent "simplicity" of the system design and operation. Although the SVE technology may be "simple" in concept, the manner in which vapors behave in the soil environment is quite complex. Recognition of this complexity led the U.S. EPA Risk Reduction Engineering Laboratory–Releases Control Branch (RREL–RCB) to convene an expert workshop to discuss the state of the art and additional research needs in the areas of site characterization, soil gas attainment of clean up criteria, and post–closure monitoring for SVE technologies.

SVE technology vendors, consulting engineers, petroleum industry representatives, university researchers, and regulatory agency

representatives took part in this workshop. The results of the presentations and discussions indicate that although similar approaches are taken in the design of SVEs, many of the pilot testing and site evaluation techniques utilized are considered proprietary in nature. According to the experts assembled, the most significant issue left unresolved with respect to remediation of an underground storage tank (UST) site via SVE is the establishment of remediation criteria and methods that can be used to determine their attainment.

Research needs that were identified and are currently being addressed include: basic research on methods to determine product concentration in soils and groundwater, vapor migration modes in heterogeneous deposits, and the nature of the residual remaining following application of SVE technologies.

The information gained during the workshop and through subsequent literature reviews and research efforts was used to develop a number of documents including: 1) SVE Technology Primer; 2) SVE Technology Assessment Report; 3) Cost Estimating Procedure for SVE Implementation; and 4) SVE Site Investigation and Pilot Testing Cost Estimation. In addition, an expert system was developed that would allow for evaluation of the efficacy of SVE for site specific applications.

ALGASORB®: A NEW TECHNOLOGY FOR REMOVAL AND RECOVERY OF METAL IONS FROM GROUNDWATERS

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Bio-Recovery Systems has developed a new sorption process for removing toxic metal ions from water. This process is based upon the natural, very strong affinity of biological materials, such as the cell walls of plants and microorganisms, for heavy metal ions. Biological materials, primarily algae, have been immobilized in a polymer to produce a "biological" ion exchange resin, AlgaSORB®. The material has a remarkable affinity for heavy metal ions and is capable of concentrating these ions by a factor of many thousand-fold. Additionally, the bound metals can be stripped and recovered from the algal material in a manner similar to conventional resins.

This new technology has been demonstrated to be an extremely effective method for removing toxic metals from groundwaters. Metal concentrations can be produced to a very low parts per billion (ppb) levels. An important characteristic of the binding material is that high concentrations of very commmon ions such as calcium, magnesium, sodium, potassium, chloride, and sulfate do not interfere with the binding of heavy metals. Waters containing a total dissolved solids (TDS) content of several thousand and a hardness of several hundred parts per million (ppm) can be successfully treated to remove and recover heavy metals. The process has been

demonstrated under the Emerging Technology program of the SITE program for the effective removal of mercury from a contaminated groundwater.

A SITE DEMONSTRATION OF ULTROX UV/OXIDATION TECHNOLOGY

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This paper presents the field demonstration results of the ultraviolet (UV) radiation/oxidation technology developed by Ultrox International of Santa Ana, California. The technology simultaneously uses UV radiation, ozone, and hydrogen peroxide to oxidize dissolved organic contaminants present in groundwater or wastewater. The demonstration was performed in February and March of 1989 at the Lorentz Barrel and Drum (LB&D) site in San Jose, California, under the Superfund Innovative Technology Evaluation (SITE) program.

The Ultrox system was evaluated for its effectiveness in treating the volatile organic compounds (VOCs) present in groundwater at the LB&D site. Experiments were conducted in which hydraulic retention time, ozone dose, hydrogen peroxide dose, UV radiation intensity, and influent pH level were varied over a wide range to assess system performance.

The Ultrox system achieved VOC removals of greater than 90 percent. Most VOCs were removed through chemical oxidation. However, for a few VOCs, such as 1,1,1-trichloroethane and 1,1-dichloroethane, stripping also contributed toward removal. The treated groundwater met the applicable discharge standards at 95 percent confidence level for disposal into a local waterway. There were no harmful air emissions to the atmosphere from the Ultrox system, which is equipped with an off-gas treatment unit.

SITE DEMONSTRATION OF A BIOLOGICAL TREATMENT OF GROUNDWATER BY BIOTROL, INC. AT A WOOD PRESERVING SITE IN NEW BRIGHTON, MN

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A wood preserving site in New Brighton, Minnesota, was selected for evaluation of a fixed film system using a biological growth inoculated with a

bacterium specific to pentachlorophenol. The pilot-plant system consisted of a three-stage mobile unit with PVC support for the growth of bacteria. After an initial acclimation period, groundwater from a well on the MacGillis and Gibbs Site was fed to the system at 1, 3, and 5 gpm with no pretreatment other than pH adjustment, nutrient addition, and temperature control. Each flow regime was maintained for about two weeks while samples were collected for extensive analyses.

At 5 gpm the system was capable of achieving more than 90 percent removal of the pentachlorophenol and effluent pentachlorophenol concentrations of about 1 ppm. At the lower flows (1 and 3 gpm) removal was at least as high and effluent pentachlorophenol concentrations were well below 0.5 ppm.

Operating costs, including power (pumping of liquids and heating), nutrients and caustic, and minimal operator attention, are quite low. This system appears to be a compact and cost-effective treatment for pentachlorophenol-contaminated wastewaters. Pre- and post-treatment requirements may exist on a site-specific basis.

SITE DEMONSTRATION OF A SOIL WASHING SYSTEM BY BIOTROL, INC. AT A WOOD PRESERVING SITE IN NEW BRIGHTON, MN

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The Soil Washer developed by BioTrol, Inc. of Chaska, Minnesota, was demonstrated on a pilot-scale under the EPA's Superfund Innovative Technology Evaluation (SITE) program in September and October 1989 at the MacGillis & Gibbs Co. wood treatment facility in New Brighton, Minnesota. The demonstration was designed to develop performance and cost data for the technology.

The BioTrol Soil Washer treats pentachlorophenol and creosote-fraction polynuclear aromatics, pollutants commonly found at wood preserving sites. The Soil Washer is an intensive, countercurrent soil scrubbing system which separates slightly contaminated coarse particles from heavily contaminated soil fines. For the demonstration two other BioTrol treatment technologies were also tested with the Soil Washer: BioTrol's Slurry Bio-Reactor and Aqueous Treatment System. The contaminated fines from the Soil Washer were treated in the Slurry Bio-Reactor, which microbiologically degrades the contaminants in a three-reactor, aerated, cascading system. The process water from the Soil Washer was treated in the Aqueous Treatment System, a multi-cell, submerged, packed-bed biological reactor for contaminated water.

The demonstration was designed to test BioTrol's claim that 95 percent of the pentachlorophenol would be removed from the coarse soil fraction, with starting concentrations of about 200 and 1,000 ppm, respectively.

At the time of the presentation only preliminary performance results and costs of the Soil Washer will be available. Complete results from this demonstration will be presented later in the final technical report.

CHARACTERIZATION OF INTERNAL INSPECTION PROCEDURES AND EQUIPMENT FOR UNDERGROUND STORAGE TANKS

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Releases from underground storage tanks (USTs) are still a prevalent problem nationwide. Internal inspections play an important role in the maintenance and prevention of hazardous releases from USTs. Existing inspection methods constitute a wide range of techniques from visual inspection to inspection using ultrasonic and magnetic testing instruments. The technical applicability of these different inspection techniques in light of the UST regulations has not been examined by EPA. The objective of this study is to characterize current techniques used for conducting internal inspections of underground storage tanks by reviewing the state-of-the-art (SOTA) internal inspection methods for both large and small USTs and the performance of these methods. The term "state of the art" has been defined as the current level of development and capability in terms of procedure, process, and technique. This study includes a review of existing industry and state standards and practitioners, as well as a review of destructive and non-destructive test methods.

Efforts are presently underway to examine the various tools and techniques used for conducting internal inspections. This study documents the significant factors that are evaluated during an inspection. Structural integrity of a UST is influenced by: wall thickness, discontinuities (e.g., pitting, perforations), and structural deflection. Several different inspection methods are used for various types of inspection. These inspections are conducted for routine maintenance, repair, lining, change in service, or upgrading. In this study, EPA is examining the application of each inspection method by identifying the procedural steps, and necessary equipment and instrumentation. EPA will present an overview of those inspection methods that are currently used by practitioners as well as innovative methods that are under development.

EVALUATION OF INTERNAL LEAK DETECTION TECHNOLOGY FOR LARGE USTs

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The performance standard for tank tightness testing established by the Environmental Protection Agency (EPA) regulation requires that the systems used to test underground storage tanks be able to detect leaks as small as 0.1 gallons per hour with a probability of detection of 0.95 and a probability of false alarm of 0.05. This standard was developed to address tanks nominally 10,000 gallons in capacity or less, but also applies to tanks as large as 60,000 gallons. The accuracy of detecting leaks in large tanks is not well known, and very little experimental data are available to make an assessment. An experimental field study is being conducted to investigate the magnitude of the volume changes that affect the performance of volumetric leak detection systems in underground storage tanks with capacities between 20,000 and 60,000 gallons. The experiments are designed to estimate the magnitude of the volume changes produced by two of the more important sources of noise that need to be compensated for in order to obtain good performance: 1) structural deformation of the tank and 2) thermal expansion or contraction of the product in the tank. The data collected in these experiments will be used to evaluate whether the models of these physical processes that were developed for smaller tanks are valid for tanks that may be ten times larger in capacity. In addition, the data obtained from several thermistor arrays deployed in the tank will be used to estimate the magnitude of the horizontal and vertical changes in the temperature of the product in the tank. This paper will describe the models, experiments, and analyses of the data.

SOURCES OF CONTAMINATION ASSOCIATED WITH CLOSURE OF UNDERGROUND STORAGE TANKS

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EPA is currently evaluating several technical and regulatory aspects of underground storage tank (UST) closures. The purpose of this project is to evaluate the effectiveness and environmental implications of various tank cleaning procedures used at closure. A common cleaning procedure, for example, involves removing pumpable residuals with a vacuum truck, manual entry into the tank to scrape residuals off the sides and bottoms (gums and sludge), and then rinsing with water. The work will attempt to

obtain a thorough technical/scientific understanding of UST residuals at closure: their origins, physical/chemical properties, ease of removal by different cleaning methods, and their environmental mobility and persistence. The information generated will be used as an aid in the regulatory process and will be useful to those implementing/overseeing closure activities.

During the course of the project, tank cleaning operations were observed for several gasoline and diesel USTs. Samples of the original residuals (present before cleaning), the residuals left after cleaning (if any), and aqueous rinseates were collected and analyzed for hazardous characteristics (e.g., flash point and corrosivity), chemical composition (including volatile organics, total petroleum hydrocarbons, heavy metals, and oil and grease) and other characteristics (e.g., pH, BOD, and TOC of the aqueous phase). Vapor concentrations were also measured at various stages in the cleaning process.

REMOVAL OF SOLUBLE TOXIC METALS FROM WATER

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The removal of selected, soluble toxic metals from aqueous solutions has been accomplished using a combination of chemical treatment and ultrafiltration. The process has been evaluated at the bench and laboratory scale, and removal efficiencies in excess of 95-99 percent have been realized. The test program at the bench scale investigated the limitations and established the optimum range of operating parameters for the process, while the tests conducted with the pilot-scale process equipment have provided information on longer-term process efficiencies, effective processing rates, and fouling potential of the membranes. Optimization of process variables, (solution pH, polyelectrolyte, polyelectrolyte concentration, and membrane material) has provided the operating range for the removal of soluble metal cations from water. With the typically-found average concentrations of the toxic metals in groundwaters at Superfund sites, the process has decreased the concentrations below the drinking water standards set by the U.S. EPA. Experiments were also conducted with concentrated solutions to determine their release from silica-based matrices. The solidified waste solutions were subjected to EP Toxicity test procedures and met the test criteria successfully. The final phase of the program involving a field demonstration at a uranium tailings site will be outlined.

LABORATORY STUDIES OF THE THERMAL DESTRUCTION OF TOXIC ORGANICS IN SEWAGE SLUDGE

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Limited field data is available concerning organic emissions from sewage sludge incinerators. This is of particular concern because hydrophobic hazardous organic compounds, such as certain pesticides, polynuclear aromatic hydrocarbons, and polychlorinated biphenyls, have been shown to partition onto the sludge during the wastewater treatment process.

Laboratory thermal decomposition studies were undertaken to evaluate potential organic emissions from sewage sludge incinerators. Precisely controlled thermal decomposition experiments were conducted on sludge spiked with mixtures of hazardous organic compounds, on the mixtures of pure compounds in the absence of sludge, and on unspiked sludge. Issues that were addressed include the effect of the sludge matrix on the thermal decomposition behavior of the hazardous sludge contaminants, potential emissions from incineration of contaminated and uncontaminated sludge, the relative contributions of the biomass and the contaminants to mass emissions in sewage sludge incineration, and potential emissions due to volatilization of organics from sludge in the drying zones of multiple hearth incinerators.

The following trends were observed:

- The sludge exerted little if any effect on the ease of destruction of very fragile contaminants.
- If a contaminant was intermediate in thermal stability, it was more difficult to destroy in the presence of the sludge.
- If a contaminant was very stable in the pure mixture, the sludge enhanced its ease of destruction.
- Fluidized bed systems appeared superior to multiple hearth for control of organic emissions.
- The majority of the observed decomposition products were from the biomass decomposition, not the spiked contaminants.

PREDICTED AND OBSERVED ORGANIC EMISSIONS FROM SEWAGE SLUDGE INCINERATION

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Samples of sewage sludge burned at three multiple hearth incinerators and one fluidized bed incinerator were subjected to laboratory flow reactor thermal decomposition testing under both pyrolytic and oxidative atmospheres. The time/temperature conditions of the laboratory tests were established to simulate as closely as possible full-scale incineration conditions such that a direct comparison of results could be made.

The laboratory test results indicated that biomass decomposition products, not toxic industrial contaminants, comprised the majority of the emissions. Benzene, toluene, ethylbenzene, acrylonitrile, and acetonitrile were consistently the most environmentally significant products of thermal exposure. Comparison to full-scale test results was complicated by two factors. First, only a limited "hit list" of primarily chlorinated hydrocarbons was analyzed in the field tests. Second, lab testing revealed that most of the potential chlorine containing compounds in the sludge samples had either evaporated or been biodegraded prior to the lab testing. However, quantitative comparison of emission factors derived from lab and field results for those compounds observed in both studies showed excellent correlation for the pyrolysis testing. Rank/order correlations were statistically significant at the 95 percent confidence level for all four sources. This suggests pyrolysis pockets of poor fuel/air mixing in the full-scale incinerators may have been responsible for many of the combustion by-products. Results also suggest that the upper stages of multiple hearth units may vaporize many volatile components of the sludge before they enter the combustion stages of the incinerator and thus represent a direct source of introduction of pollutants into the atmosphere.

CHARACTERIZATION OF TWO MWC ASHES AND LEACHATES – A FIELD STUDY

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This paper has been written based on data obtained during a study conducted for the United States Environmental Protection Agency (U.S. EPA) and the coalition of Resource Recovery and the Environment (CORRE). Incineration of municipal solid waste (MSW) has become an

important alternative to the land disposal of MSW. Incineration is an effective means of reducing the volume of MSW and can provide an important source of energy. Ash from the combustion of household waste has been excluded from regulations under Subtitle C of the Resource Conservation and Recovery Act (RCRA), which regulates disposal of hazardous waste. However, in some instances, testing the residues from municipal waste incinerators by the Extraction Procedure (EP) Toxicity test is being required to determine if these residues would be classified as hazardous waste and, therefore, subjected to disposal regulations under Subtitle C.

Ashes from municipal waste combustion (MWC) facilities, on occasion, have exhibited hazardous waste characteristics as determined by the EP Toxicity test. The debate regarding the representativeness and the validity of this test and the relation of these results to actual leachates from ash disposal facilities has not been settled. For this reason, U.S. EPA and CORRE have cosponsored an NUS Corporation study designed to enhance the data base on the characteristics of MWC ashes, laboratory extracts of MWC ashes, and leachates from MWC ash disposal facilities.

NUS collected MWC ash samples from five facilities and leachate samples from the companion ash disposal facilities. These ash and leachate samples were analyzed for the Appendix IX semi-volatile compounds, polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs), metals with primary and secondary drinking water standards, and several miscellaneous conventional compounds. In addition, the ash samples were analyzed for major components, in the form of oxides. The ash samples were subjected to six different laboratory extraction procedures, and the extracts were then analyzed for the same compounds as the ash samples. All sampling, laboratory preparation, and analyses followed stringent quality assurance/quality control (QA/QC) procedures. Pertinent information regarding the operating conditions of the facilities, as well as information about the air pollution control equipment used by the facilities, was obtained.

The major findings of this study are described in this paper.

MOBILITY OF DIOXINS AND FURANS ASSOCIATED WITH STABILIZED INCINERATION RESIDUES IN THE MARINE ENVIRONMENT

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Combustion of municipal solid wastes produces huge amounts of residual ash requiring disposal. Stabilization of incineration ash into solid concrete-like materials has been achieved using Portland cement. In April

1987, and again in September 1988, small artificial reefs fabricated using stabilized incineration ash blocks were submerged in Conscience Bay, Long Island Sound, along with appropriate control materials. Divers have returned periodically to remove blocks and evaluate the effects of seawater submersion on the physical and chemical characteristics of the material.

Data collected over the period of submersion show the blocks have maintained their structural integrity, and that stabilization has effectively immobilized metal and organic constituents of environmental concern. When compared to preplacement values, dioxin and furan analyses of the blocks suggest that no measurable amount of leaching has occurred. Analyses of mussel and hydroid tissues, two organisms closely associated with the reefs, indicate that no uptake of these organics has been realized.

If the data continue to suggest that stabilized incineration ash can be placed into the sea to construct offshore artificial fishing reefs with no adverse environmental impacts, then a novel and beneficial method for the utilization of this waste material may have been realized.

WATER MOVEMENT THROUGH AN EXPERIMENTAL SOIL LINER

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A field-scale soil liner was built to address the feasibility of constructing a liner to the hydraulic conductivity specifications of the U.S. EPA (i.e., less than 1×10^{-7} cm/s), to assess the areal variability of a liner's hydraulic properties, and to determine the transit time for water and tracers through the liner. The liner, measuring 8 x 15 x 0.9 m, was constructed in 15-cm compacted lifts using full-scale compaction equipment and standard engineering practices.

Monitoring infiltration rates into the liner by large- and small-ring infiltrometers and a pond water balance for one year provide estimated saturated hydraulic conductivities of 2.4×10^{-9}, 4.0×10^{-8}, and 5.0×10^{-8} cm/s, respectively. Based on geostatistical analysis and the small variances exhibited by the small-ring flux data, the liner is homogeneous with respect to infiltration rates.

Transit time prediction of water breakthrough at the bottom of the liner ranges from 2 to 10 years, depending on the method of calculation and assumptions used. The liner appears to be saturated to a depth greater than 20 cm, tension saturated to a depth of at least 70 cm, and unsaturated at its base. Thus, validation of the transit time calculations is currently not possible because breakthrough has not yet occurred. The liner will continue to be monitored for a minimum of one year.

EVALUATING THE ABILITY OF RECOMBINANT BACTERIA TO DEGRADE PCBs ON SOIL

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The presence of large quantities of polychlorinated biphenyls (PCBs) in the environment has generated considerable interest in the development of an economical means for the destruction of these compounds. *Pseudomonas* sp. LB400 is a bacterial strain capable of enzymatically degrading a wide variety of PCB congeners. Genetic studies have demonstrated that PCB degradation by LB400 involves a cluster of genes (designated *bphA, B,C,* and *D*) located within a 12.4-kilobase region of DNA. A variety of recombinant plasmids containing the LB400 *bph* genes were introduced into cells of *Escherichia coli* and the PCB degrading abilities of the resulting recombinant strains compared to that of LB400 in resting-cell assays. Recombinant strain FM4560 (containing *bphA, B,* and *C*) was similar to LB400 in its ability to degrade Aroclor 1242, as well as several other PCB mixtures. Preliminary data indicate that FM4560 has several characteristics which could be advantageous in a PCB biodegradation process. These include a high growth rate, greater survivability, and high "constitutive" activity. A study has recently been initiated to examine whether these properties enable FM4560 to better degrade PCBs on soil than does the naturally occuring *Pseudomonas* strain LB400.

DEGRADATION OF CHLORINATED BIPHENYLS BY ESCHERICHIA COLI CONTAINING CLONED GENES OF THE PSEUDOMONAS PUTIDA F1 TOLUENE CATABOLIC PATHWAY

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Pseudomonas putida F1 initiates the degradation of toluene by a multicomponent enzyme system designated toluene dioxygenase. The enzyme system consists of a flavoprotein (reductase $_{TOL}$), a ferredoxin (ferredoxin $_{TOL}$), and an iron-sulfur protein (ISP $_{TOL}$). Electrons are accepted from NADH by reductase $_{TOL}$ and transferred through ferredoxin $_{TOL}$ to the terminal dioxygenase, ISP $_{TOL}$. Reduced ISP $_{TOL}$ catalyzes the addition of molecular oxygen to the aromatic nucleus stereospecifically to form *cis*-dihydrodiols from a variety of aromatic substrates. The *cis*-dihydrodiols are oxidized to catechols which are the substrates for *meta* ring cleavage by catechol dioxygenase. Certain bacteria that degrade polychlorinated biphenyls (PCBs) utilize an analogous pathway. Homology studies between PCB degrading strains and *P. putida* F1 have indicated that the enzymes involved are quite similar. We have constructed strains of *Escherichia coli* that express the cloned genes of the

P. putida F1 toluene catabolic pathway under the control of the *tac* promoter. These strains were utilized to show that the initial enzymes in the toluene catabolic pathway can also oxidize certain chlorinated biphenyls.

USE OF DNA HYBRIDIZATION PROBES IN THE MONITORING OF BIOTREATMENT SYSTEMS

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Spurred by recent technological advances, significant progress has been made in the application of DNA hybridization probes for the characterization of microbial communities in situ. A review will be presented of relevant methodologies now available for such analyses as well as several examples of their use. In conjunction with on-going studies at the U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory and the University of Cincinnati on the treatability of toxic organic compounds in different bioreactor systems, we have initiated studies to apply DNA probe technology towards the characterization of resident microbial populations in such systems. These studies will include: 1) the isolation and characterization of bacterial strains with degradative capabilities toward a number of different target toxicants from sludges or other sources; 2) respirometric determinations of target compound degradation rates by these and other previously characterized pure strains compared with mixed sludge populations; 3) preparation of DNA hybridization probes specific for the degradative strains; and 4) use of the probes for detecting and enumerating the degradative strains in bench-scale activated sludge and fixed film reactor systems fed with different concentrations of the target compounds and alternative substrates. These results will be used to assess the relative colonization, maintenance, and functionality of the different degradative strains in the two reactor systems and to determine the relationship between these factors and the overall degradative performances of the reactors.

BIODEGRADABILITY STUDIES OF THE ALASKAN WEATHERED CRUDE OIL CONSTITUENTS WITH THE USE OF ELECTROLYTIC RESPIROMETRY AND SHAKER FLASK SYSTEMS

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Bench-scale biodegradability studies of the Alaskan weathered crude oil constituents were undertaken as part of the overall bioremediation project for the shorelines of Prince William Sound, Alaska, contaminated by the Exxon oil spill. The purpose of the studies was to evaluate the capability of the indigenous microbial consortium of the sea water and the coastline and island beach areas in the vicinity of the oil spill, to biodegrade and/or biotransform the spilled weathered crude oil alkane hydrocarbon and polynuclear aromatic (PAH) constituents in batch-type respirometric reactors and shaker flask systems.

The schematics of the experimental respirometric biodegradation testing protocol and the procedural experimental steps of the shaker flask approach are discussed, providing information on the experimental and control systems (inoculum, inoculum plus fertilizer, toxicity, positive reference compound, and physical-chemical controls) used in the studies to test the biodegradability of the crude oil components with the different fertilizers as sources of nutrients.

Biodegradation data reported in this paper are those generated from studies that incorporated the use of INIPOL EAP 22 as the fertilizer nutrient source.

Respirometric studies have provided results based on the cumulative oxygen uptake data, growth data, and the GC scans and GC/MS analysis data which demonstrate almost complete utilization of the alkane hydrocarbon constituents in the presence of INIPOL fertilizer and very significant biodegradation of the PAH constituents in the culture media after six weeks of incubation.

Control respirometric and shaker flask experiments without the INIPOL provided data which demonstrate an absence of biodegradative activity of the alkane hydrocarbons and PAH oil components.

BIOLOGICAL TREATMENT OF WASTEWATER CONTAINING HAZARDOUS ORGANIC COMPOUNDS: 2-ETHOXYETHANOL

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Biological treatment is one potential technology for treatment of RCRA-listed wastes containing hazardous organic compounds in concentrations up to 1 percent (10,000 mg/L), provided that the compounds are not recalcitrant or toxic to the microorganisms in the system. As part of the U.S. EPA's in-house testing program at the Test & Evaluation Facility, biological treatment was evaluated as a treatment technology for 2-ethoxyethanol, a solvent that can occur as the major constituent in RCRA-listed F005 wastes.

Respirometry and the anaerobic toxicity assay (ATA), respectively, were used to screen 2-ethoxyethanol for toxicity under both aerobic and anaerobic conditions. Toxicity did not occur in the concentration range studied (0 mg/L - 10,000 mg/L) under either condition, and the data implied that biodegradation occurred.

Pilot-scale activated sludge systems were subsequently used to further evaluate the fate of 2-ethoxyethanol in aerobic systems. The pilot-scale systems were operated at a flow rate of approximately 11 liters per day for a 24-hour hydraulic residence time with a target solids retention time of 10 days. The systems were supplied with a synthetic feed which was spiked with 2-ethoxyethanol, and the concentration of 2-ethoxyethanol was measured in feed, effluent, waste sludge, and reactor off-gas samples. At the highest feed concentration studied, the system reduced the 2-ethoxyethanol concentration from 2,284 $\pm$ 174 mg/L in the feed to 18 $\pm$ 15 mg/L in the effluent. No 2-ethoxyethanol was detected in the off-gas or waste mixed liquor samples.

BENCH-SCALE BIODEGRADATION STUDIES WITH ORGANIC POLLUTANTS USING WHITE ROT FUNGUS

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Over the past decade, many investigators have demonstrated the capacity of the White Rot Fungus (*Phanerochaete chrysoporium*) and/or its enzymatic products (ligninases) to degrade an array of naturally occurring and anthropogenic waste materials. The results have inspired the further investigation of use of the fungus in a Bioreactor (Rotating Biological Contactor) for optimization of operational parameters for treatment efficiency and scale-up practicality.

Cometabolism is employed by the organism in the distinct phases of growth and biodegradation. Both have been observed and evaluated under various conditions of operation. These variables include rotational speed of the RBC, concentration of glucose used as growth substrate, and concentration of ambient oxygen. Included is a discussion of the performance by the organism toward the organic substrates when not induced into secondary metabolism. The substrates include the chlorinated, aromatic, and color producing compounds in the effluent of the paper pulping industry. Synthetic media composition with spiked compounds are treated as well.

Evaluation of results has been based on the reduction of substrates, longevity of treatment capacity, and physical observation of those factors of interest to larger scale/commercial applications. Focus of the study has been to develop reproducibility as well as ease of operation and assessment of optimum growth requirements and ligninase enzyme synthesis conditions in bench-scale bioreactors for the attainment of treatment efficiency of organic pollutants in scale-up treatment systems.

EXPERIMENTAL METHODS/RESULTS OF ASSESSING SOIL WASHING TECHNOLOGY

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The U.S. Environmental Protection Agency through its Risk Reduction Engineering Laboratory's Release Control Branch has undertaken research and development efforts to address the problem of leaking underground storage tanks. Under this effort, EPA is currently evaluating soil washing technology for cleaning up soil contaminated by the release of petroleum products from leaking underground storage tanks. Soil washing is a dynamic physical process in which soluble contaminants are extracted from the solid fraction into liquid medium, usually water. In addition, the separation of the highly contaminated fine soil particles (silts, clays, and colloids) from the bulk of the soil matrix is accomplished through the mechanism of volume reduction. As a result, a significant fraction of the contaminated soil is cleaned and can be returned into the original excavation or used as cleaned "secondary" fill or aggregate material. Since the contaminants are more concentrated in the fine soil fractions, their separation and removal from the bulk soil increases the overall effectiveness of the process. Subsequent treatment will be required for the spent wash waters and the fine soil fractions.

The soil washing program evaluated the effectiveness of soil washing technology in removing petroleum products (unleaded gasoline, diesel/home heating fuel, and waste crankcase oil) from the EPA Standardized Soil Matrix (SSM) as well as from actual Underground Storage Tank (UST) site soils. Optimal conditions determined from experiments with SSM have been applied to bench-scale testing of actual UST site soils.

Bench-scale experiments were conducted in order to obtain sensitivity analysis curves on various parameters affecting soil washing efficiency including contact time, wash water volume, rinse water volume, wash water temperature, and chemical additives to the washing solution such as surfactants and degreasing agents. The findings from these experiments, as well as the experimental design of the bench-scale tests will be discussed.

VACUUM–ASSISTED STEAM STRIPPING TO REMOVE POLLUTANTS FROM CONTAMINATED SOIL—A LABORATORY STUDY

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A project is underway to evaluate the vacuum–assisted steam stripping procedure for removal of organic contaminants from soils. The first two years of the study were devoted to determination of basic parameters such as steam permeability and pollutant removal. A wide variety of soils were used and the "pollutants" were kerosene and a series of simple organic chemicals of widely varying boiling points and polarities. These results were reported in the previous two Symposia. The vacuum–assisted steam stripping technique appears to have significant potential for pollutant removal from soils.

The present work concentrates on the ultimate removal efficiency of the method, utilizing a wide variety of soil types and chemicals. Soils are used which also contain some clay and some organic content, to better simulate soils encountered in the field. Steam pressure and temperature are also varied in the present work. The chemicals include the alkanes and alkane–based alcohols plus benzene, ethyl benzene, toluene, and xylene (BETX) to approximately simulate gasoline. Gas chromatography is used to determine the amount of chemical remaining in the soil after a prescribed vacuum–assisted, steam stripping procedure.

LIMITED–USE CHEMICAL PROTECTIVE CLOTHING FOR EPA SUPERFUND ACTIVITIES

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Due to complaints from field personnel regarding poor durability and fit of limited–use disposable chemical protective clothing (CPC) used at hazardous waste site operations, the U.S. Environmental Protection Agency (EPA) initiated a study to:

- o Characterize EPA use of CPC;
- o Determine problems encountered;
- o Develop solutions to problems;
- o Develop procurement guidelines.

Two Superfund hazardous waste sites were surveyed regarding problems with CPC. Poor fit of coveralls and lack of fabric durability resulted in garment failures, especially in the seat, crotch, and underarms.

The commercial market was surveyed and commercial fabrics used for limited-use CPC were identified and obtained where possible. In addition, two experimental fabrics were obtained. The fabrics were tested for breaking strength and flexibility. Based on these tests and the field survey, acceptable minimum values for breaking strengths of coated and uncoated fabrics, and acceptable maximum values for stiffness were determined. One of the experimental fabrics was found to be promising when compared to these values, demonstrating that fabrics with improved strength and adequate flexibility could be developed at a cost acceptable to EPA activities.

Available standards and specifications describing size and fit parameters for limited-use CPC were identified and clothing meeting those of interest were examined. None was thought to be acceptable for use by the EPA. However, American National Standards Institute (ANSI) Standard 101-1985 was found to provide a baseline for development to EPA requirements. EPA problems were analyzed and suggested changes to ANSI 101 and additional requirements for EPA applications were developed.

STRESS CRACKING OF POLYETHYLENE FMLs

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Due in large part to their excellent chemical resistance, polyethylene resins are commonly used for liners in solid waste landfills and liquid surface impoundments. This resistance comes about from the relatively high density (approximately 0.94 g/cc and greater) of the material versus other available liner materials. A caution, however, is that polyethylene in this density range is also susceptible to "stress cracking", which is brittle failure that can occur at less than the yield stress. In recognition of this possibility, this paper is focused on an exploration of existing test methods and the development of new test methods to be used in material selection and qualification of polyethylene Flexible Membrane Liners (FMLs) to provide the best possible stress crack resistance. The focus is on four separate tasks:

(a) The incubation liquid and test temperature of the commonly used ASTM D-1693 bent strip test method should be upgraded from its present conditions to a 10 percent Igepal solution in tap water at 50°C. Furthermore, the test duration should be extended from 500 to 1,500 hours.

(b) A new test method based on notched constant tensile stress specimens should be implemented. These tests result in the identification of the FML's ductile-to-brittle transition time which should be greater than 100 hours.

(c) Field seams should be evaluated in a constant tensile stress mode at 45 percent of their yield in sets of 20 specimens. Tentatively, we recommend that none should fail within 24 hours, five (or fewer) in 100 hours, and the average failure time of the 20 must be more than 300 hours.

(d) Lastly, we recommend that the surface temperature of exposed polyethylene FMLs should not exceed 50°C (122°F). This can be achieved in a number of different ways which will be discussed.

LANDFILL TEST CELLS

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The Delaware Solid Waste Authority has constructed two landfill cells, each one acre (0.405 Hectare) in size, at its Central Waste Management Center near Dover, Delaware. Each cell is being filled with household solid wastes generated in housing areas in and around Dover, Delaware. Each cell has identical, flexible membrane liners (FML). The primary liner is made up of four strips, each 50 ft (15.24 meters) in width and consisting of 36-mil Hypalon, 36-mil CPER, 30-mil CPE, and 30-mil PVC. Both cells have a 30-mil PVC FML as the secondary liner. The primary liner in each cell is separated from the secondary liner by identical drainage systems. The leachate from each cell is collected and stored in an insulated aboveground storage tank. Each cell catchment area has a flow measurement device to measure and record runoff. After closure, leachate from the test cell #1 will be recirculated through the cell, and test cell #2 will remain dry. Leachate from each test cell is undergoing chemical analysis under a research grant from the U.S. EPA. The paper will report on the construction and filling operations of the test cells. This project is expected to provide field-scale data to verify the HELP (Hydrologic Evaluation of Landfill Performance) Model and measure the effects of leachate recirculation.

REVISION OF THE HELP MODEL

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The Hydrologic Evaluation of Landfill Performance (HELP) Model was initially released in June 1984. Subsequently, two verification studies were performed, and the model has had widespread use and testing. The Hazardous and Solid Waste Amendments were enacted, and new minimum

technology requirements were developed. Also, new technology has become available for use in landfills. These events have yielded numerous recommendations for revision of the HELP Model. In response, drafts of Version 2 HELP have been developed, and its final draft is presently being completed.

The climatological data requirements have been changed to support a synthetic weather generator and a vegetative growth submodel added to the HELP Model. The soil data input has been changed to allow specification of the initial moisture content of the various layers of material in the landfill profile. In addition, the default soil data base has been updated.

Small revisions have been made to routines used to compute snowmelt, surface evaporation, plant transpiration, and soil evaporation but the fundamental methods used are unchanged from the original version. The vertical drainage model has been updated to use a Brooks-Corey formulation for computing unsaturated hydraulic conductivity and vertical drainage. The lateral drainage model has been replaced with a new non-dimensionalized analytical solution of the Boussinesq equation. Additional submodels are now being prepared for inclusion in the final draft of this version. These include a method for determining the effect of surface slope of runoff, for estimating leakage through flexible membrane liners, and for modeling lateral drainage from synthetic drainage nets. Other revisions have also been made, particularly in the output.

WASTE MINIMIZATION ASSESSMENTS AT SELECTED DOD FACILITIES

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The Waste Reduction Evaluations at Federal Sites (WREAFS) Program was established as part of the Agency's pollution prevention research effort with three overall goals. These goals are to: 1) conduct a series of waste minimization opportunity assessments at selected federal sites; 2) conduct cooperative research, development, and demonstration studies within the federal community; and 3) develop technology information transfer among federal activities and between industry and government. This paper focuses on the results of waste minimization opportunity assessments which were conducted jointly between EPA and selected DOD facilities.

One example of a joint EPA/DOD waste minimization opportunity assessment includes using the EPA "Waste Minimization Opportunity Assessment Manual" to conduct a project in cooperation with the Environmental, Safety, and Health Department of the Philadelphia Naval Shipyard. The industrial areas selected for evaluation were Building 990 – aluminum cleaning and spray painting; Building 1028 – spray painting of steel parts including structural columns; and the citric acid bilge cleaning operations conducted in drydock. The options that were evaluated include

equipment, personnel/procedure, and material-related alternatives developed by the assessment team. The most viable options are projected to result in a significant annual cost savings. The information presented will be useful to those in the decision making process for the selection of waste minimization options at both public and private sectors where similar operations are being performed. The assessment reports document study procedures, feasibility analyses, study findings, and recommendations. The proactive role of the federal community for pollution prevention is an essential part of this Nation's cleaner environment.

CHEMICAL SUBSTITUTION OF TRICHLOROETHYLENE AND METHANOL IN MANUFACTURING OPERATIONS

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Trichloroethylene (TCE) is used as a cold solvent degreasing agent in many industrial processes. In 1986, TCE was identified as a hazardous waste that must be managed under Subtitle C of the Resource Conservation and Recovery Act. As a result, industries began investigating ways to avoid using TCE-based cleaning solvents. EPA's Pollution Prevention Research Branch along with APS Materials, Inc., a small metal finishing company, participated in a joint research project to evaluate the substitution of a dilute terpene-based cleaner for TCE in degreasing operations.

This paper presents the results of a study evaluating the waste reduction/pollution prevention that can be achieved by substituting dilute terpene-based solvent solution for TCE and methanol in the cleaning of orthopedic implants. This paper describes the original cleaning process, the modifications made to the process in using the dilute terpene-based solvent solution, and the sampling plan used in evaluating the effectiveness of the solution. The paper presents qualitative results of the sampling tests and an economic evaluation of plant modifications.

WASTE MINIMIZATION ASSESSMENT CENTERS

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In 1988, University City Science Center (Philadelphia, Pennsylvania) began a pilot project to assist small- and medium-size manufacturers who want to minimize their formation of hazardous waste but who lack the in-house expertise to do so. Under agreement with the Risk Reduction Engineering Laboratory of the U.S. Environmental Protection Agency, the Science

Center's Industrial Technology and Energy Management (ITEM) division established two waste minimization assessment centers (WMACs) at Colorado State University in Fort Collins and at the University of Tennessee in Knoxville. During the second program period of the project, a third WMAC established at the University of Louisville (Kentucky) has begun to conduct assessments.

Each WMAC is staffed by engineering faculty and students who have considerable direct experience with process operations in manufacturing plants and who also have the knowledge and skills needed to minimize hazardous waste generation. The waste minimization assessments are conducted at no out-of-pocket cost to the client. Several site-visits are required for each client served. The WMAC staff locate the sources of hazardous waste in each plant and identify the current disposal or treatment methods and their associated costs. They then identify and analyze a variety of ways to reduce or eliminate the waste. Specific measures to achieve that goal are recommended, and the essential supporting technological and economic information is developed. Finally, a confidential report which details the WMAC's findings and recommendations including cost savings, implementation costs, and payback times is prepared for each client manufacturer.

This presentation will discuss results from the first period of this project.

VETERANS ADMINISTRATION HOSPITAL WASTE MINIMIZATION CASE STUDY – CINCINNATI, OHIO

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The U.S. EPA has initiated a broad program of pollution prevention to support continued environmental improvements throughout the nation. The Agency, responsive to the national concern in regard to evidence of the improper disposal of medical wastes, is initiating projects to evaluate the generation, collection, transportation, treatment, and disposal of medical wastes. A good first step for any hospital seeking to reduce its liability in this area is to conduct an assessment of the waste minimization opportunities in its facilities.

In cooperation with the EPA, the Veterans Administration Hospital in Cincinnati, Ohio, conducted a waste minimization assessment of its activities that produce hazardous or infectious wastes. An EPA contractor compiled all facility waste generation information, management constraints imposed by health and safety regulations, VA policies, and agreements with labor unions or waste disposal firms, and other influences on waste management alternatives. During the assessment, the entire path taken by products destined to become medical waste was examined, beginning with the initial procurement, through inventory, actual use, post-use handling, treatment, and ultimate disposal.

During the assessment it became clear that the VA Hospital, driven by its sensitivity to health care costs, has in place some very effective waste minimization practices. Unlike most hospitals, the VA does not have access to private insurance and therefore cannot assign costs on a per bed basis. As a result, the generation of medical waste is well below the average level for a hospital of this size.

A TEN–YEAR REVIEW OF PLASTICS RECYCLING IN THE U.S. AND EUROPE

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A short discussion of the waste minimization program now in operation at EPA is given, and how it leads to the establishment of an overall program to encourage recycling in general, a part of which is plastics recycling. The origins of the major types of plastics now being collected for recycling are outlined, along with the present procedures for collection and recycling. The author suggests that recycled thermoplastics may be technically, economically, and environmentally desirable in the durable good and automotive sectors where "new" parts may be made of recycled material. These parts may be hidden in the compressor or engine compartments, or they may be of such quality that they could be used on appearance terms such as headlight bezels. If sufficient care is taken in the collection, separation, and remolding of discarded plastics products, parts of acceptable quality may be made at considerable savings in both money and the amount of waste discarded, freeing landfill or incinerator space for non–recyclable materials. To help us achieve our goal of recycling a major portion of more than 60 billion pounds of plastics produced annually, much more research and development is needed in the area of recycling and in the physical properties and processing of recycled materials. New regulations allow EPA to jointly fund projects with both industrial firms and non–profit institutions. Ideas for such projects are actively solicited.

EVALUATION OF EPA WASTE MINIMIZATION ASSESSMENT

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The costly disposal of hazardous waste from industrial processes continues to be a growing concern and affects companies of all sizes. Environmentally–aware owners, plant managers, and engineers realize the need for taking immediate action, but do not always have the immediate resources to do what is necessary to reduce waste generation. In support, the EPA initiated several tasks related to identifying waste minimization opportunities. Under an EPA contract, SAIC is conducting waste minimization opportunity assessments at five or six facilities following the EPA "Waste Minimization Opportunity Assessment Manual." Under another effort, three waste minimization assessment centers were established at

the Colorado State University, the University of Tennessee, and the University of Louisville through the University City Science Center (UCSC). Waste minimization assessment studies will be conducted by these centers to assist small- and medium-sized manufacturers who want to minimize waste generation but lack the expertise to establish waste minimization programs. Under a cooperative agreement with the New Jersey Department of Environmental Protection, 30 assessments, as self-audits, are being conducted at New Jersey companies in fiscal year 1990. Technical assistance is being provided by the New Jersey Institute of Technology. The status of each of these assessment activities will be presented in this paper along with a preliminary evaluation of the assessment procedure's effectiveness.

SLURRY-BASED BIOTREATMENT OF STILL BOTTOMS SORBED ONTO SOIL FINES

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Research focus is on the biodegradation of organic contaminants on fine fractions, separated from whole soil. Leachates or aqueous extracts from whole soil are also of importance. Waste activated sludge from conventional secondary treatment provides mixed microbial populations for semi-continuous slurry reactor configurations. To date, operations have been carried out under aerobic conditions. However, at some point, a sequence of aerobic/anaerobic steps will be evaluated. Whole soil samples were obtained from a site immediately adjacent to an impoundment used for disposal of still bottoms. This waste is the residue of benzene, toluene, and xylenes (BTX) production by distillation of a high molecular weight petroleum feed stock under strong acid conditions. Chlorinated aromatic wastes have been detected in the otherwise dominantly hydrocarbon material.

Contaminants are a diversity of extremely complex multi-ring compounds. Thus, relative concentrations of representative compounds are monitored during biodegradation. In many instances, the factor of choice is gas or liquid chromatogram peak height, as a function of carrier, instrument temperature program, and reference residence time. Feed rate and the role of phenol as a co-substrate are manipulated experimental variables. Significant reductions of marker-species concentration, often to levels below detection limits, are observed with low, medium, and some high molecular weight polynuclear aromatic hydrocarbon (PAH)-type compounds, as well as the chlorinated species.

ANAEROBIC TREATMENT OF LEACHATE

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An upflow anaerobic filter (volume: 800 gal and EBCT: 3.7 days) followed by a conventional activated sludge system (HRT: 5.6 hr and SRT: 8 days) was used to determine the fate and effect of hazardous leachate in anaerobic-aerobic systems. The leachate flowrate to the anaerobic filter was 0.15 gpm. Screened raw municipal wastewater (0.85 gpm) and the filter effluent were added to the conventional activated sludge system. Selected organic compounds and heavy metals were spiked to the synthetic leachate (C-source: acetate, propionate, and butyrate; total feed COD: 1,600 mg/L) to simulate a typical hazardous leachate.

The results showed that selected heavy metals at design concentrations did not cause any adverse effects on the anaerobic process. Among the organic toxicants, the removals of chlorobenzene and toluene were low (15-25%), whereas the removals of acetone, methyl ethyl ketone, methyl isobutyl ketone, trichloroethylene, methylene chloride, and 1,1-dichloroethane exceeded 90 percent. The removal of all added organic compounds by the combined anaerobic-aerobic process exceeded 90 percent. Hence, an upflow anaerobic filter preceding a conventional activated sludge process appears to be effective in treating hazardous leachates.

THE EFFECTS OF TEMPERATURE, CONCENTRATION OF SUBSTRATE AND MICROBIAL INOCULUM, AND THE SOURCE OF SLUDGE BIOMASS ON THE KINETICS OF BIODEGRADATION

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Biodegradation kinetic data base will enable the classification of biodegradability and the inhibitory effects on the sludge biomass of the toxic organic Resource Conservation and Recovery Act (RCRA) and

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Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) pollutant compounds. The biokinetic data will provide the basic pilot- and full-scale treatability information and an accurate assessment of the need for pretreatment for these toxic pollutants.

Electrolytic respirometry approach involving natural sewage, sludge, and soil microbiota was demonstrated to be a very successful, accurate, cost effective, and less labor intensive method for generating biodegradability/inhibition and biokinetic data.

A developed multi-level respirometric protocol is presented for the determination of the biodegradability, microbial acclimation to toxic substrates, and first order kinetic parameters of biodegradation and for estimation and quantitation of Monod kinetic parameters (U_m, K, and Y) of the toxic organics, in order to correlate the extent and rate of their biodegradation with a predictive model based on chemical properties and structure of those organic pollutant compounds. Respirometric biodegradation kinetic data are provided for representative RCRA alkyl benzenes, phenolic compounds, phthalate esters and ketones, and CERCLA leachate organics.

Studies were undertaken to determine the effects of the source of sludge biomass, temperature and concentrations of microbial inoculum, and of toxic substrate on the generated biodegradation kinetic parameter data in order to make an assessment of their constancy under a variety of environmental conditions.

A predictive biodegradation structure-activity model based on the group contribution approach was developed with the use of respirometrically generated biodegradation kinetic data. The predictive biodegradation fate model will closely predict the results found experimentally. Fate of structurally related toxic organics may be anticipated without the time and expense of experimental studies.

CHEMICAL COMPATIBILITY OF GEOTEXTILES, GEONETS, AND PIPES USED IN HAZARDOUS WASTE CONTAINMENT

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Despite the advanced technology displayed by the U.S. chemical industry, there exists little comparable technology capable of dealing with the billions of tons of improperly disposed toxic chemical waste. Due to this lack of technology, research in the field of geosynthetics used in hazardous waste containment was begun approximately 10 years ago. One problem facing the advancement of modern geosynthetic technology is the lack of consistent testing methods. For this purpose, a project was undertaken to develop a technological base for predicting the long-term durability and compatibility of geotextiles, geonets, and pipes in contact with hazardous waste.

In the initial phase of this project, an extensive literature search was conducted on existing information to investigate the performance and failure criteria for these geosynthetics. From this literature review, an article was prepared on the geotextiles, geonets, and pipes used in landfill sites; types of polymeric materials; exposure; and characterization methods. In addition to focusing on the available information of the chemical compatibility of geosynthetics, this review has identified some areas of current and future study, such as the use of analytical techniques to determine the molecular interaction between geosynthetic materials and leachate components.

In the second phase, chemical compatibility testing of geosynthetics necessitated the formulation of idealized leachate recipes and development of novel accelerated aging techniques. Handling of chemicals and equipment required the establishment of safety and handling procedures. Recommendations for new guidelines for use of geotextiles, geonets, and pipes in hazardous waste facilities are now being formulated based upon the results of the study. More complete failure mechanisms will allow for better design and materials choices in future landfill sites.

STABILIZATION/SOLIDIFICATION FOR TREATMENT OF SUPERFUND SOILS

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This research program was initiated with the overall objective of determining the effectiveness of the stabilization/solidification process in reducing the mobility (as measured by the Toxicity Characteristic Leaching Procedure) of metals and pesticides in actual Superfund soils. Another objective of the study was to determine how well the stabilization/solidification process performed on actual Superfund soils versus a synthetic soil matrix.

Superfund soils from the Tri-State Metals Plating Site in Columbus, Indiana, and the Syncon Resins Site in Kearney, New Jersey, were selected for bench-scale stabilization/solidification testing at International Technology Corporation's (IT) Technology Development Laboratory in Knoxville, Tennessee. IT conducted screening tests to determine optimum water ratios and binder ratios using three commonly used binders: Portland cement, lime/flyash, and kiln dust. Water-to-total solids ratios of 0.20 to 0.44 and binder-to-soil ratios of 0.5, 0.75, and 1.0 were used for testing. Samples prepared in triplicate were allowed to cure under controlled conditions for 28 days and then subjected to unconfined compressive strength (UCS) testing. The minimum binder-to-waste ratio for each binder type which exhibited a UCS value greater than 50 psi was selected for

chemical analysis. IT and a contract laboratory program (CLP) laboratory (Ecology and Environment, Inc. in Buffalo, New York) performed the chemical analyses.

Analytical results are presented for the untreated and stabilized/solidified Tri-State Metals Plating and Syncon Resins soil; volatile organic compound (VOC) headspace analyses during sample curing; and the Portland cement, kiln dust, and lime/flyash binders. The untreated and treated Tri-State soils were analyzed for total waste analysis (TWA) and toxicity characteristic leaching procedure (TCLP) metals; total organic carbon (TOC); humic acid content; grain size distribution; and cation exchange capacity. Syncon Resins, both untreated and treated, were analyzed for TWA and TCLP metals, pesticides, and polychlorinated dibenzofurans; TOC; humic acid content; grain size distribution; and cation exchange capacity. Binders were analyzed for TWA and TCLP metals. In addition, UCS values, bulk densities, volumes, weights, and curing conditions are reported.

TREATABILITY OF TRIBUTYLTIN IN POTWs

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Organotin-contaminated wastewater generated during drydock cleaning operations must be treated before discharge to the environment. A study was conducted to assess the treatability of tributyltin in a conventional primary/activated sludge municipal wastewater treatment plant. Experiments were conducted to evaluate the treatability and fate of tributyltin by both abiotic and biotic mechanisms.

Sorption isotherms were measured for tributyltin and its degradation products on primary sludge mixed-liquor solids and digested sludge. Partition coefficients ranged from 1,585 to 13,200 for monobutyltin and tributyltin, respectively. The organotin compounds were not removed by stripping.

Both aerobic and anaerobic biotic mechanisms were studied for degradation of tributyltin. Steady state aerobic degradation levels in the range of 75-95 percent were observed with sludge retention times of 8-18 days. In anaerobic studies, biological methane potential and anaerobic toxicity assays showed no effect on the performance of methanogens.

GUIDE FOR CONDUCTING TREATABILITY STUDIES UNDER CERCLA

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Systematically conducted, well-documented treatability studies are an important component of the remedial investigation/feasibility study (RI/FS) process under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These studies provide valuable, site-specific data necessary to aid in the selection of the remedy. This guide, which is being issued in interim final form, focuses on treatability studies conducted before the Record of Decision (ROD) has been signed; however, treatability studies may well continue into the remedial design/remedial action (RD/RA) phase.

The guide describes a three-tiered approach for conducting treatability studies that consists of: 1)laboratory screening, 2) bench-scale testing, and 3) pilot-scale testing. Depending on the information gathered during site characterization and technology screening and the data gaps that exist, treatability studies may begin with any tier (e.g., bench-scale testing) and may skip tiers that are not needed (e.g., laboratory screening followed by pilot-scale testing).

The guide also presents a stepwise approach or protocol for conducting treatability studies for determination of the effectiveness of a technology (or combination of technologies) in remediating a CERCLA site. The steps include:

- Establishing data quality objectives
- Selecting a contracting mechanism
- Issuing the Work Assignment
- Preparing the Work Plan
- Preparing the Sampling and Analysis Plan
- Preparing the Health and Safety Plan
- Conducting community relations activities
- Complying with regulatory requirements
- Executing the study
- Analyzing and interpreting the data
- Reporting the results

The intended audience for this document comprises Remedial Project Managers, responsible parties, contractors, and technology vendors.

IMPLEMENTING A WASTE MINIMIZATION PROGRAM AT THE A.W. BREIDENBACH ENVIRONMENTAL RESEARCH CENTER

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EPA's recent emphasis on pollution prevention includes all waste-generating activities, hazardous and non-hazardous, affecting all media. An ongoing waste minimization program has been implemented at the A.W. Breidenbach Environmental Research Center through development of a Pollution Prevention Steering Committee and performance of an initial waste minimization opportunity assessment. The assessment included analytical and research laboratory activities, as well as office operations and building maintenance procedures. Implementation costs and benefits were projected for all waste minimization recommendations.

BIOLOGICAL AND PHYSICO-CHEMICAL REMEDIATION OF A MERCURY-CONTAMINATED HAZARDOUS WASTE

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Biological removal of mercury from contaminated water and sediments involves enzymatic reduction of ionic mercury (Hg^{2+}) to the elemental form (Hg°) and subsequent volatilization or precipitation of this hazardous metal. The process has been successfully tested in the laboratory. The goal of this project is to investigate application and to further develop the technology, when necessary, for remediation of mercury-contaminated water and sludges at an actual site.

Preliminary results indicate that the process can be used at a site contaminated with Hg^{2+} and high NaCl concentration ($\leq$ 50 g/L) to remove >99.98 percent of Hg^{2+}. The reduced Hg can be precipitated or volatilized. Final disposition of most of the Hg° is controlled by aeration rate, hydraulic retention time, and Hg^{2+} loading rate.

Volatilized Hg° is trapped by adsorption on activated carbon (AC). Sorption isotherms developed for AC show that only 0.04 percent Wt/Wt Hg° can be adsorbed. Work is in progress with adsorption of Hg° on impregnated AC, which shows promise of adsorbing up to 100 times more Hg°. Hg adsorbed on AC can be desorbed by heating. Desorbed vaporous Hg can be condensed for reuse.

STEAM STRIPPING AND BATCH DISTILLATION FOR REMOVAL AND/OR RECOVERY OF VOLATILE ORGANIC COMPOUNDS

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The Risk Reduction Engineering Laboratory of the U.S. EPA Office of Research and Development is conducting treatment technology assessments for the RCRA listed hazardous wastes, at its Cincinnati Test and Evaluation (T&E) Facility. As a part of this program, pilot-scale testing is being conducted to evaluate the performance of steam stripping and batch distillation for removal and/or recovery of volatile organic compounds. A 2-inch I.D. steam stripping column with packing equivalent to 20 theoretical plates has been selected for the testing. The batch distillation unit has a 125-gallon batch still and a 6-inch I.D. column with packing equivalent to 50 theoretical plates. At present these units are in different stages of testing and shakedown. To date, steam stripping runs have been performed with toluene, isopropanol, and 2-nitropropane. Different computer programs, for prediction of vapor-liquid equilibrium data, have also been reviewed. Selected programs have been modified for use at the T&E Facility. A bench-scale unit is currently being set up to experimentally determine required vapor-liquid equilibrium data.

OZONE/ULTRAVIOLET LIGHT TREATMENT OF FERRI-CYANIDE COMPLEXES

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Recent concern ove" the quantity of total cyanide being disposed of in landfills and discharged to surface waters has prompted the U.S. EPA Office of Solid Waste to begin investigating alternative treatment methods for electroplating wastewater. UV-aided ozonation of ferri-cyanide complexes is one of the technologies currently being evaluated at the U.S. EPA Test and Evaluation Facility in Cincinnati. Ferri-cyanide complex is the

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major cyanide source remaining after the destruction of free cyanide by alkaline chlorination. UV-aided ozonation had been reported to have promise for treatment of ferri-cyanide complexes. In the current work the effects of different parameters, such as UV light intensity, temperature, ozone flow rate, and initial ferri-cyanide concentration, on the destruction rate of the ferri-cyanide complex is being studied. This work will also include the determination of the effect of ozone activation by UV light in a separate chamber prior to ozone introduction into the reactor containing the ferri-cyanide solution.

THE U.S. EPA/WRITE PROGRAM

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In 1989, the U.S. EPA entered into cooperative agreements with six states (California, Connecticut, Illinois, Minnesota, New Jersey, and Washington) to participate in a new pollution prevention research program called Waste Reduction Innovative Technology Evaluation (WRITE). In this three-year program, the states work with industry to demonstrate and evaluate source reduction and recycling technologies to reduce or eliminate waste. Technology evaluations will include both engineering effectiveness and cost analysis. This presentation will focus on two of these WRITE programs, Illinois and New Jersey.

1) Illinois

In June of 1989, the Illinois Hazardous Waste Research and Information Center (HWRIC) and the U.S. EPA began a three-year program. Some projects under consideration include substituting water-based or soybean-based inks in printing processes and substituting a citrus cleaner for chlorinated solvents in metal fabricating and printing processes. The approach to the program will be discussed including results to date, technologies used, and roadblocks to waste reduction.

2) New Jersey

In August of 1989, the New Jersey Department of Environmental Protection (NJDEP) and U.S. EPA began this three-year project. Some of the technologies being considered are: an electroplating wastewater recycling system; substitution of a colloidal compound cleaner for degreasing operations; membrane technology used in the recovery of nitric and sulfuric acids from ammonium salt splitting; and other projects. Discussion of the project will include results to date, obstacles encountered, and technologies under evaluation.

AMERICAN INSTITUTE FOR POLLUTION PREVENTION

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The University of Cincinnati has joined with the U.S. EPA to form the American Institute for Pollution Prevention (AIPP). The Institute's primary goal is to generate broad support from the public and private sector and assist EPA in achieving the widespread and expeditious adoption of pollution prevention concepts.

The EPA approach to pollution prevention is unique among all other EPA environmental protection efforts in that it is not a regulatory-based, adversarial-type program. Rather, it must achieve success by relying on information transfer and persuasion with respect to both the motivation of pollution generators to incorporate pollution prevention practices and the method from a technical viewpoint, by which pollution prevention can be achieved.

AIPP members have been nominated by their respective trade organizations or professional societies and have individually demonstrated numerous accomplishments in the field of pollution prevention. They have all agreed to serve voluntarily because of their continuing interest in environmental protection. The AIPP has formed four councils to address its goals in the areas of education, economics, technology, and implementation.

EPA'S POLLUTION PREVENTION INFORMATION CLEARINGHOUSE (PPIC)

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EPA has developed its Pollution Prevention Information Clearinghouse (PPIC) to assist state and local agencies, industry, other Federal agencies, academic institutions, the public, and even foreign organizations in accessing technical, policy, and other information on pollution prevention. PPIC features both a "telephone hotline" and a computerized communication network, the Electronic Information Exchange System (EIES). PPIC offers a wide array of clearinghouse services including an ability to search abstracts of pollution prevention reports and articles, a hard-copy repository of important documents in the field, a document-ordering and disseminating capability, as well as a linkage to other related data bases. During the poster session PPIC will be described in some detail and demonstrated for attendees.

IRF UPDATE 1990

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The U.S. Environmental Protection Agency operates an experimental combustion research facility in Jefferson, Arkansas. One of its functions is to evaluate thermal treatment of hazardous wastes. The Incineration Research Facility (IRF) is operated as a research station to perform incinerator studies which assess process conditions, design, and operating parameters that affect the destruction of hazardous wastes. Measurement of treatment efficiency or destruction and removal efficiency (DRE), residue quality, and air emissions are among the research objectives.

This poster will document the physical changes that were made to the facility in the recent past and discuss the trace metals partitioning and soil remediation projects that have been carried out since renovation.

DEVELOPMENT AND DEMONSTRATION OF A PILOT-SCALE DEBRIS WASHING SYSTEM (DWS)

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A large number of hazardous waste sites in the United States are littered with metallic, masonry, and other solid debris which may be contaminated with hazardous chemicals (e.g., polychlorinated biphenyls [PCBs], pesticides, lead, or other metals), and in some cases clean-up standards have been established (10 μg PCBs/100 cm^2 for surfaces to which personnel may be frequently exposed). Although the majority of debris at Superfund sites does not possess the potential for reuse, the debris could, following decontamination, either be returned to the site as "clean fill" in lieu of transporting the debris offsite to a hazardous waste landfill or, in the case of metallic debris, be sold to a metal smelter.

During previous phases of this project we have developed a technology for performing on-site decontamination of debris. Both bench-scale and pilot-scale versions of a Debris Washing System (DWS) have been designed and constructed. The DWS utilizes an aqueous solution which is

applied to the debris during a high pressure spray cycle followed by a turbulent wash cycle. The aqueous cleaning solution is recovered and reconditioned for use concurrently with the actual debris cleaning process; therefore the quantity of process water utilized to clean the debris is minimized.

In this paper we present the results obtained during a field demonstration of the DWS. Data will be presented which are indicative of the effectiveness of the system for removing PCBs from the surfaces of metallic debris, as well as the efficiency of the closed-loop solution reconditioning system which is built into the DWS. The performance of the DWS under adverse (sub-freezing) temperatures at a hazardous waste site located in Hopkinsville, Kentucky, will also be discussed.

ENGINEERING HANDBOOK FOR HAZARDOUS WASTE INCINERATION

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One of the most difficult, and time-demanding, tasks for a permit writer is to evaluate and interpret incinerator designs and to determine whether the construction and testing of a hazardous waste incinerator will cause an unreasonable impact on health and the environment. In addition, individuals must understand the fundamentals of incinerator construction and operation to design trial burns and to evaluate the results. This paper describes the revised Engineering Handbook for Hazardous Waste Incineration, a document due to be published in late 1990, which will provide guidance on the basic principles, concepts, and designs of hazardous waste incinerators. The Engineering Handbook will also give methods that can be used to estimate the performance of the incinerator and its ancillary equipment.

The Engineering Handbook is an extensive revision and update of SW-889, a document by the same name which was published in 1981. It is a compilation of information from the open literature describing current techniques and equipment used for hazardous waste incineration. The document is not intended to be a detailed design handbook; rather it is intended as a reference for those individuals who are associated with the regulatory aspects of the subject. It is specifically aimed at permit writers and regulators who are generally unfamiliar with the field and need a central source of basic information. As such, its main emphasis is on the evaluation of equipment and its design to assess how well new incinerators, whose designs are being evaluated prior to construction, are likely to achieve their function in a safe and environmentally sound manner. The

Handbook also contains fundamental thermodynamic and kinetic information and techniques that can be used to evaluate, design, and operate a facility.

ASSESSMENT OF THE CURRENT STATE OF THE ART FOR BIO/PHOTODEGRADABLE PLASTICS

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The purpose of this assignment is to assist EPA in developing a set of criteria or test parameters to support Federal regulation of the disposal of plastic products, including consumer-use items made of polymers such as polyethylene, polyvinyl chloride (PVC), and polystyrene. There is strong concern about the fate and ecological effect of these products in the soil and marine environments. Objective methods are needed to define degrees of degradation, deterioration, and decomposition, and to judge the relevance and value of engineering tests. The main objective is to establish criteria to ascertain the point at which degrading plactic products no longer pose a threat to the environment.

The scope of work includes two primary tasks. The first task is to examine current or proposed state and local regulations for dealing with plastics degradation and legislated bans on non-degradable plastics found in the waste stream. The second task is to identify and assess degradation test parameters currently in use to characterize enhanced degradation of plastic materials.

Information on legislation and technical standards has been received from 26 states. Several states currently have legislation proposed. Although most state legislation is focused on six-pack beverage carrier rings, other products and materials are also being examined. Criteria for technical standards are being developed by several groups in the professional and industrial community.

FIELD TESTS OF HYDRAULIC FRACTURING TO INCREASE FLUID FLOW IN SOILS

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Fluid flow in the soil subsurface is a basic requirement of many methods of in situ remediation, including pump and treat, soil flushing, vapor extraction, bio-remediation, and steam stripping. Hydraulic fracturing is a method of increasing fluid flow to improve the effectiveness of those in situ methods, especially in areas where flow is limited by material of low permeability. Basically, hydraulic fracturing involves injecting fluid into a well until pressures exceed a critical value and fracturing begins. Sand is then

pumped into the fracture to hold it open and provide a high permeability channelway. The process was developed more than 50 years ago to increase the yields of oil wells. Last year at this Symposium we reported results from our first field test where we used oil-field equipment to show that it was possible to create hydraulic fractures at shallow depths in soil-conditions typical of many contaminated sites.

Shortcomings of the 1988 test led us to redesign equipment and methods of hydraulic fracturing at shallow depths. The new method was field tested in June 1989, with the creation of 23 fractures at two sites in Cincinnati. Nineteen of those fractures were excavated to examine their size, thickness, and orientation. Other fractures will be used to examine how they affect flow rates to wells. The fractures all contained sand and they reached a maximum thickness of one inch and a maximum length of 28 feet. As many as four flat-lying fractures, stacked one on top of another at spacings as close as 6 inches, were created from the same borehole. Venting of the fractures to the ground surface was reduced compared with results from 1988.

We are planning to test hydraulic fracturing during the remediation of a contaminated site in F.Y.'90.

BARRIER EQUIVALENCY OF LINER AND CAP MATERIALS

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The objective of this project is to investigate materials that might be used as hydraulic barriers in liners or covers to replace or augment a low-permeability, compacted soil liner. In the first year of investigation, potentially equivalent barrier materials were identified, and available data for the materials were collected, tabulated, and analyzed. Additional data that would be needed to determine the equivalency of the barriers were identified. In the next year of study, tests will be performed to aid in determining the equivalency of the materials to an FML (flexible membrane liner) or a low-permeability soil liner.

The materials that were investigated included blended soils, amended soils, manufactured blankets of clay, waste materials, concrete, sprayed-on materials, and manufactured FML/clay composites. The materials fell into two categories: 1) materials that would have to be custom-designed and evaluated for each project, and 2) manufactured, "off-the-shelf" materials, the properties of which would not have to be repeatedly studied. Future emphasis will be placed on the second category of materials. The greatest amount of data and experience in the field was found for thin blankets of bentonite attached either to geotextiles or FMLs. These materials show promise as equivalent barriers, but more data are needed to define characteristics of seam overlaps, puncture resistance, resistance to desiccation and frost action, and similar performance parameters.

SITE DEMONSTRATION OF THE AWD's AQUADETOX/VES SYSTEM

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Preliminary results from the Superfund Innovative Technology Evaluation (SITE) demonstration of AWD's AquaDetox Vapor Extraction System (VES) will be presented in this poster. The AquaDetox/VES System couples air and steam stripping with vapor extraction techniques to remove volatile organic compounds from ground, air, and water in a closed-loop system in which each individual system's discharge is treated by the other system.

According to the developer, the steam stripping system involves pumping groundwater into a column that is kept at a moderate vacuum. The contaminated water cascades down from the top of the column through packing material, while steam, heated to 130 degrees Fahrenheit, is introduced at the bottom. The steam heat causes the contaminants to vaporize. The vapor is separated, condensed, and further processed to segregate the solvent, which can then be recycled or disposed. Vapors that will not condense are sent to the VES for further treatment. The stripper and the VES share a granulated activated carbon (GAC) unit. The VES draws ground air through the GAC that adsorbs solvents. Non-condensable vapor from the stripper is combined with the vapor from the VES compressor and decontaminated by the GAC unit. Finally, any water pumped with the air is redirected to the vacuum steam stripper for treatment. Water that emerges from the bottom of the column is clean and may be safely discharged into the sewers.

GUIDANCE ON METALS AND PICs CONTROL FROM HAZARDOUS WASTE INCINERATION

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The U.S. Environmental Protection Agency is currently working on regulations to control metals and products of incomplete combustion (PIC) emissions from combustion in hazardous waste incinerators, boilers, and industrial furnaces. Guidance manuals have been published for use by the permit writers so that they can implement the necessary controls in the interim until the rules are promulgated, using omnibus authority provided under RCRA. The methodology to control carcinogenic metals (arsenic, beryllium, cadmium, and chromium) emissions has been provided such that incremental lifetime risk to the maximum exposed individual does not exceed 1 in 100,000. PIC emissions control is provided using carbon monoxide (CO) and total hydrocarbon (THC) emissions as surrogates. CO must be monitored continuously, and hourly average emission rate should not generally exceed 100 ppmv. In cases where CO emissions are higher, compliance must be demonstrated by THC emissions not exceeding 20 ppmv on an hourly average basis.

The regulatory proposal for hazardous waste incineration in boilers and industrial furnaces was published in the Federal Register on October 26, 1989, while that for incinerators is expected for publication in February 1990. The final promulgation is expected in 1991 for both proposals.

REDUCTION OF TRANSIENT PUFFS FROM A ROTARY KILN INCINERATOR: THE ROLE OF THE SECONDARY COMBUSTION CHAMBER

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Experiments on a 73-kW (250,000-Btu/hr) rotary kiln incinerator simulator equipped with a 58.4-kW (200,000-Btu/hr) afterburner/control temperature tower were performed to examine the effect of the secondary combustion chamber on reducing transient puffs generated during the batch charging of surrogate solid and liquid waste. In this preliminary set of tests, the effect of temperature was examined in the absence of flame contact and turbulent mixing. A first-generation mathematical model was derived using a plug flow reactor simulation. Preliminary data indicate that not only does the secondary chamber provide a reduction in the absolute magnitude of a puff, but also considerably alters the composition of the puff, with respect to both chemical species and biological activity.

THE USE OF ELECTROKINETICS FOR HAZARDOUS WASTE SITE REMEDIATION

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This study was performed to assess the state of the art of electrokinetically enhanced contaminant removal in soils. Prior research efforts, both laboratory and field, have demonstrated that electroosmosis has the potential to be effective in facilitating the removal of certain types of

hazardous wastes. Particularly encouraging results have been achieved with inorganics in fine-grained soils where more traditional removal alternatives such as pump and treat are less effective.

Although the results of various studies suggest that electrokinetics is a promising technology, further testing is needed at both the laboratory and field levels to fully develop this technology for site remediation. A conceptual test program is presented based on best available data which incorporates system design and operating parameters used in previous applications of this technology.

GROUND PENETRATING RADAR-EQUIPPED FIELD ROBOTIC VEHICLE FOR SURVEYING CERCLA SITES

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For years, robotics and automation have increased productivity in manufacturing industries through standardization and repeatability. Core robotic technologies have now progressed to the point that robots are moving into the field and offering the same benefits. One such implementation is subsurface mapping of waste sites — the process of spatially correlating non-invasive measurements in order to graphically represent the geometry of buried structures. Through a cooperative agreement with the U.S. EPA, the Field Robotics Center is developing a subsurface mapping system based on a mobile robot that deploys ground penetrating radar (GPR) transducers.

The prototype Site Investigation Robot (SIR) maintains knowledge of its location on site and carries a scanning mechanism that provides the local positional accuracy necessary for GPR imaging. GPR data are digitized and stored in memory for subsequent digital filtering, specialized geophysical processing, and image enhancement. These processes transform the radar data into a subsurface map which is displayed on a computer graphics terminal and stored in the site data base. While we have demonstrated these techniques for two-dimensional GPR images, the focus of our current research is development of processing techniques that exploit the three-dimensional nature of GPR and create 3-D subsurface maps.

DETOXIFICATION OF RELEASED VAPORS/PARTICULATES BY ENTRAPMENT IN CHEMICALLY ACTIVE FOAMS

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In the wake of the Bhopal disaster, there has been increasing public and governmental concern over the possibility of toxic gas and vapor releases from chemical plants. Title III of SARA, Superfund Reauthorization and Amendment Act of 1986, specifically addresses emergency preparedness for such releases. Industry is under intense pressure to provide additional safeguards to prevent "gas" clouds from threatening populated areas.

Many ways to prevent releases are already in use by industry ranging from safety-conscious plant design, through safety alarms and interlocks, to backup devices such as scrubbers and flares. However, once a gas or vapor leak occurs, the options for its control are few.

Under study is the use of "foam scrubbing," a novel option for controlling emergency releases of airborne toxics. In this approach, foam is generated with conventional equipment using the contaminated air. The foaming solution contains neutralizing agents and may require a special surfactant system for compatibility. With the airborne materials encapsulated in the foam, a large interior liquid surface area is available for gas, vapor, aerosol, or particulate sorption. Neutralization agents present in the bubble walls can then react with the entrapped toxic gas or vapor to render it innocuous. The foam collapses to yield a processable liquid.

This proposed technology has potential applications to emergency control; among these are fixed installations in plants and portable units for field use by emergency response teams.

ASSESSMENT OF MATERIAL HANDLING TECHNOLOGIES

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A typical Superfund or other hazardous waste site contains hazardous chemicals which are frequently intermingled with remnants of razed structures as well as contaminated soil, gravel, concrete, and metallic

debris. Specialized materials handling and classifying technologies are needed to deal with the large quantities of these various types of contaminated materials present at the site prior to, or in conjunction with, decontamination and disposal operations. The objective of this study is to summarize the types of debris, material, and contaminants found at Superfund and other hazardous waste sites in EPA Region V and the materials handling equipment and general procedures that have been implemented to perform site restoration and cleanup.

This paper provides information on state-of-the-art materials handling equipment and procedures that would be useful for addressing difficult, site-specific, materials handling problems. The capabilities, performance, applicability for hazardous waste site work, and costs for a variety of materials handling techniques will be discussed. Case studies for sites within EPA Region V will be presented which include detailed information concerning debris, material, contaminants found on site, and the specific materials handling needs and problems encountered. In addition, the materials handling technologies currently used in the United Kingdom and West Germany will be briefly summarized.

EXCALIBUR OZONE/ULTRAVIOLET/ULTRA SONICS

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This poster will describe the Excalibur/Ozonics technology which is designed to treat soils and liquids with organic and inorganic contaminants. The technology is a two-stage process; the first stage extracts the contaminants from the soil, and the second stage oxidizes the extracted contaminants in water. Ultrapure water and ultrasound are used to extract the contaminants from the soil. The oxidation process involves treatment with ozone, ultraviolet light, and ultrasound. The ultrasound is used as a catalyst to enhance the soil washing.

In addition, the treatment system uses carbon filters that are biologically activated to regenerate the spent carbon in situ to treat the off-gas from the reactor.

Ideally, solid material needs to be less than one inch in diameter. Size of the treatment units can vary according to the specific site needs. The process can be applied to soils, solids, sludges, leachates, and groundwater. Contaminant concentrations may range from 1 ppm to 20,000 ppm.

METAL TREATMENT BY ADSORPTIVE FILTRATION

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Treatment of solutions containing toxic metals at Superfund sites is complicated by the wide range of concentrations which may be present and the complexity of the matrix. Although highly concentrated metals may be treatable by conventional precipitation processes, these processes may not meet the stringent effluent discharge requirements. Also, metals are often present in relatively low, but still unacceptable, concentrations in the effluent from treatment processes for removal of organic contaminants.

The process being tested in this project is one which combines an efficient sand filter with an adsorption process capable of lowering metal concentrations well below levels achievable by precipitation alone. The process uses a conventional sand filter in which the sand is first coated with iron oxide. The iron oxide surface has a strong, pH-reversible affinity for the metals. The fact that the oxide is physically attached to sand grains rather than a suspended material makes it much easier to work with, and allows the filtration of particulate metal contaminants to proceed simultaneously with adsorption from the soluble phase. Finally, the process is applicable to anionic metals such as chromate, selenite, and arsenate, which are difficult to precipitate efficiently.